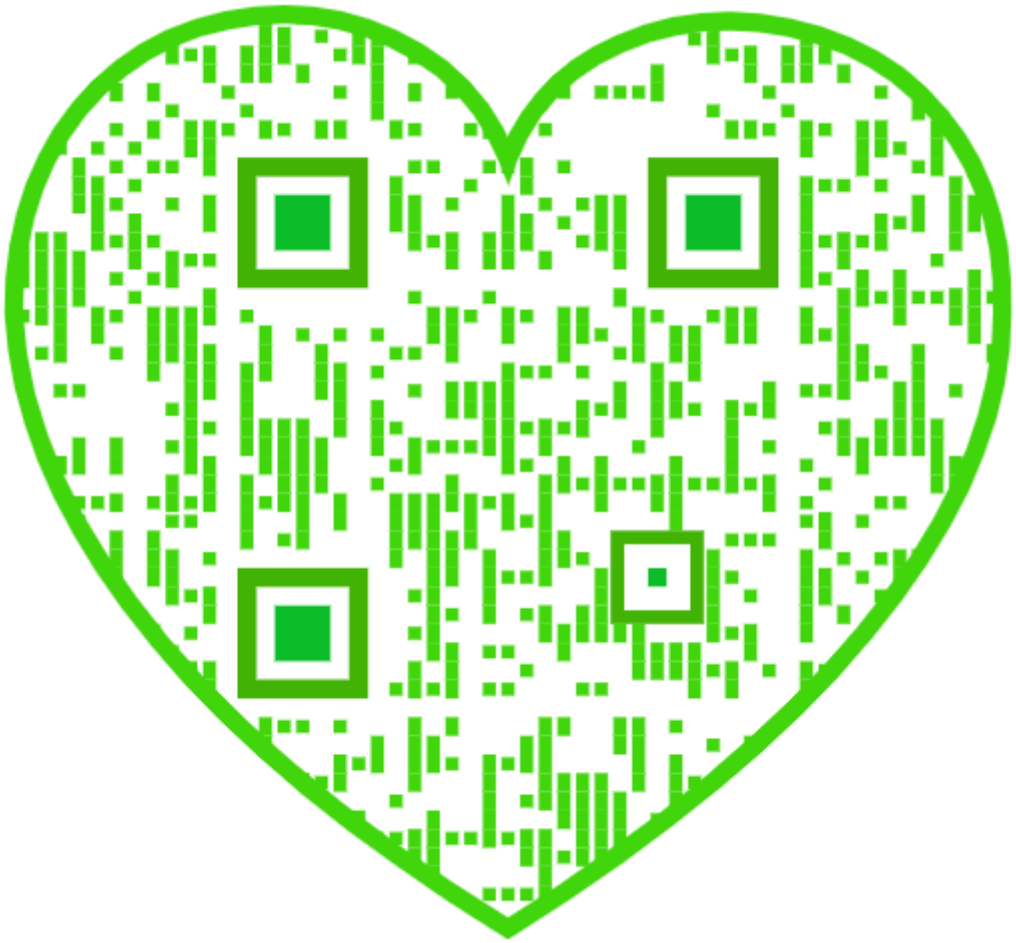

COTTON SPINNING

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TORONTO

COTTON SPINNING

BY

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AND WEAVING TO THE WEST RIDING OF YORKSHIRE

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PREFACE TO FIRST EDITION

This, the second volume, reprinted from *The Textile Mercury*, brings the subject of cotton spinning down to the end of what is generally termed the preparing processes. It includes all the machinery and manipulations between the card and the self-actor or ring-frame. As the operations included in this section have a most important influence upon the future character of the yarn, it has been considered necessary to go a little more deeply into the subject than is usually thought necessary. Attention has not only been confined to the principles underlying the actual processes themselves, which is of itself a most interesting and important feature, but in conformity with the objects that prompted the writing of the first volume, an effort has been made to give to the mechanical details an interpretation which some of them have hitherto not possessed.

It was with this purpose in view that the writer remarked in the preface to the first volume that the book would not be one of "mere description." The remark was meant to

be applied to the whole subject of cotton spinning; in this volume a reasonable claim may be made that it is justified, and the third volume, dealing with the spinning processes, will still further prove the writer's objects and method.

The fact that at present the education of the average reader is not sufficiently thorough to enable him to understand fully some aspects of the question discussed is no reason why an attempt at completeness should not be made. Such a state cannot last very long. The systems now being adopted in our technical schools will raise the general level of intelligence, and, moreover, a feeling will grow that we "must" so raise ourselves if we are to maintain the practical superiority over our competitors which we at present claim. W. S.-T.

Bolton, 1897.

PREFACE TO SECOND EDITION

Improvements and corrections have been made and the drawings renumbered, so that the book is entirely self-contained. This system of dividing the subject of cotton spinning into three volumes has been justified: it fits in with the arrangements for study and the examinations, and meets the requirements of those employed in the various departments of the mill. W. S.-T.

1900.

PREFACE TO FIFTH EDITION

THE book has been brought up to date and considerable additions made both to the matter and the illustrations. The author and publisher hope that these improvements will cause it to maintain its career as a useful handbook to the student and the practical man.

WM. SCOTT-TAGGART.

BOLTON, 1913.

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CHAPTER I

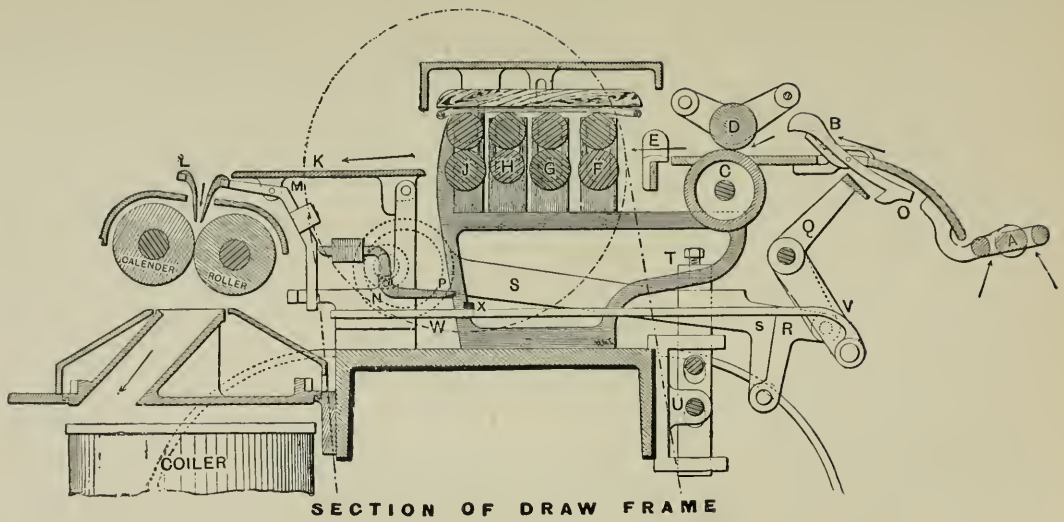
DRAWING

The Web from the Card.—A close examination of the web or film of cotton as it comes from the doffer of the carding engine will disclose an arrangement of fibres quite contrary to what might at first sight be expected when the action of the card is understood. Instead of order, a very irregular result will be noticed. The specific action of the condensing process between the cylinder and doffer, however, will account for much of the crossed condition of fibres, and the stripping operation of the comb will still further increase the irregularity of their disposition in the web. It is this irregularity of arrangement that enables the cotton to be stripped from the doffer and carried forward to the calender rollers. Any parallelisation in such a thin web would render it practically impossible to free the fibres from the doffer—much less to carry them away, as at present. A point, however, that must not be overlooked, is seen very clearly in the web as it approaches the calender rollers of the card. Between the doffer and the calender rollers there is always a draft; and, moreover, the mere fact of causing a web of cotton, which is the full width of a card, to converge very quickly

NOTE.—A very complete set of practical notes on these machines will be found in the author's book, *Cotton Mill Management*.

towards a point, will make every fibre in the web partake of the convergence, in whatever crossed condition it may be. This constitutes, of course, a distinct tendency to laying the fibres side by side, which is further augmented by the action of the draft in pulling the fibres apart. Such an action as this cannot be performed without straightening them considerably, the friction existing between them being sufficient to cause the individual fibres to straighten in sliding over one another. Although this is apparently an insignificant action, it is in reality the very keynote of the process of drawing; for while in this process great reliance is placed upon obtaining a regular sliver, it must not be overlooked that success in the operation almost depends entirely upon the fibres being laid parallel, which state is brought about because of the friction between them during the drawing action being sufficient to straighten them out.

Description of the Drawing-Frame.—Before entering upon a detailed investigation of the drawing-frame and its action, a general description of the machine will be given. To do this a drawing is represented in Fig. 1, which represents a section, through the chief features, of a well-known type of frame as made by Dobson and Barlow. The full cans of sliver are taken from the card and put behind the draw-frame, so that the sliver can be passed up in the direction of the arrows through holes in the guide-plate A. On going forward, each sliver passes over a spoon-shaped guide B, and on between two rollers C and D, whence it is guided to the back-roller F by means of the traverse guide E. Four successive lines of rollers are now passed, during which the sliver is considerably drawn out or attenuated in consequence of each roller having a greater surface speed relative to the one next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R
U
COILER
SECTION OF DRAW FRAME

Fig. 1.

to it. This is an essential feature of the machine, and it is from this fact that the name "drawing-frame" is derived. On emerging from the roller J the drawn sliver is taken over a polished plate K, through the funnel L, and on between the calender rollers to the coiler. The above is a general description; we now enter into details. The guide-plate A is arranged so that it can be carefully adjusted according to the position of the cans from which the slivers are taken. Large quantities of waste are easily made by carelessness in setting it, due to the breakages that occur through too great a drag being put on the sliver in passing through the holes. The draw-frame is arranged so that each sliver that enters the rollers is drawn out four to eight times its original length, and four to eight slivers are passed through together, so that, although each one is so lengthened out, their combination at the funnel L, through which they pass, produces a sliver which differs very little in weight or length from any one of the entering slivers; it is more regular in substance, and its fibres are drawn out, comparatively speaking, parallel to each other. (The principles underlying these actions are explained on page 14.) Otherwise there is no noticeable difference between a sliver fed at the back and that delivered at the front of the machine. Six ends or slivers are generally passed through, and in such a case the total draft between the rollers will be six. Each drawing-frame is split up into what are termed **heads**, a head being that portion of the rollers through which a group of slivers pass. For instance, if six slivers, side by side, pass through the four lines of rollers and are combined into one at the funnel, that section of the machine is called a **delivery**, and a **set** of deliveries is called a **head**. As a rule, there are from two to four heads in a complete draw-frame (see Figs. 2, 3,

and 4). This diagram illustrates three methods of arranging draw-frames. In Fig. 2 we have the **tandem** system in which the deliveries are all one way. It will be observed that there are 24 cans behind the machine; six ends pass through each of the four deliveries, so that only four ends emerge at the front. These ends would be taken to another passage of draw-frames, and possibly to a third. Fig. 3 illustrates the **alternate** system, in which the slivers follow the arrow, and an extension of this

FIG. 2. FIG. 3.

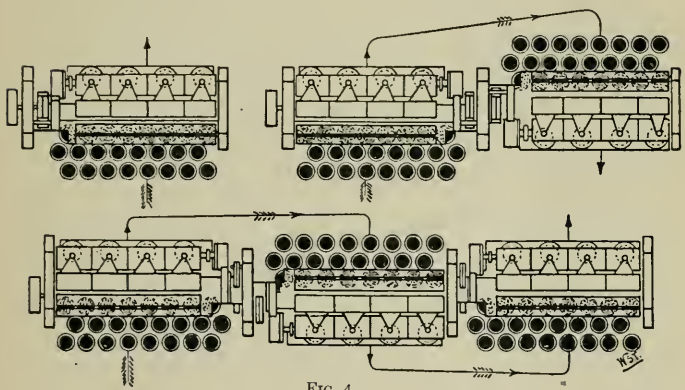


FIG. 4.

arrangement results in a modification known as the **zig-zag** system. These different systems are the outcome of convenience to the work hands, economy of labour, and suitability of driving, as well as a saving in room and power. It must be understood that a wide variation may exist in the size of draw-frames. Each head may have eight deliveries, instead of four, as shown; there may be three heads of seven or eight deliveries; in fact, there is scarcely a limit to the utilisation of the draw-frame for its purpose of drawing and doubling slivers. The length

of rollers in each delivery varies from 15 in. to 18 in.; this length refers to the top rollers. Each of the bottom rollers is generally made in one length, or in sections pieced together so that they revolve as one length. These bottom rollers are fluted—that is, grooves are cut therein lengthwise—in order that a grip may be obtained of the cotton as it passes through, and also that this grip shall prevent the cotton from slipping or being drawn from between the rollers in consequence of the draft. The number of the flutes, of course, varies in different frames, but they are usually as follows:—1 in. diameter, 36 flutes; $1\frac{1}{4}$ in. diameter, 45 flutes; $1\frac{3}{8}$ in. diameter, 50 flutes; $1\frac{1}{2}$ in. diameter, 54 flutes. The arrangement of the flutes, especially where the top rollers are covered with leather, is such that they have a slightly decreasing pitch on the circumference. It will be seen that by this means the chance of the flutes making corresponding grooves in the leather, or actually cutting it, through continual working, is considerably reduced when compared with the effect produced if the flutes be all pitched alike. The general term used to designate this kind of fluting is **hunting**, and its effect is similar to that of the 'hunter cog' adopted by clockmakers, and formerly by engineers, in having the number of the teeth of wheels in gear so arranged that the same teeth come into touch with each other only after a number of revolutions.

Rollers.—It will readily be seen that since the drawing action of the machine is such an important factor in its usefulness, every means must be adopted to enable it to perform this part of its work perfectly. The grip of the various pairs of rollers, or their power to draw the fibres over each other without breaking or straining them, must be carefully attended to, for carelessness in this respect will

simply mean waste, and considerable irregularity in the resulting sliver.

The top rollers, although heavy, are not sufficiently so to dispense with additional weighting, and, generally speaking, draw-frame rollers are weighted by some system of supplementary weights. As a rule, dead weights are adopted, *i.e.* weights sufficient for the purpose are hung by means of wire or cast-iron hooks from each end of the roller (see Fig. 5). In such a case the weights would probably vary from 14 to 25 lbs. if each end were weighted separately, but very frequently one weight is used for both ends; when this method is adopted the weights must be double what they were in the first case. The actual weight required depends upon the special circumstances in each mill, and is largely a question of experience. Many people would adopt weights of something like the following:— Front roller, 22 lbs.; second roller, 17 lbs.; third roller, 17 lbs.; and fourth roller, 17 lbs. Here the front roller is naturally more heavily weighted than the others, because of the greater bulk of cotton going through at this point; but the others are all alike in weight, the draft between them not being so great, and consequently there is no great necessity for any variation. There are, however, many authorities who advocate different weights on each line of rollers, and they would most probably arrange them as follows:—Front roller, 20 lbs.; second roller, 18 lbs.; third roller, 16 lbs.; and fourth roller, 14 lbs. It may also be noted that some arrangements for the lower class cottons and heavy slivers have slightly heavier weights than for the finer classes of cottons. It is, however, very much a question of experience, and in deciding upon the question a full consideration must be given to all the factors of the case.

Leather Rollers.—The leather covering of the top rollers has already been mentioned: The adoption of such a covering on the top rollers of cotton machinery is necessitated by the fact that two iron rollers revolving in contact, with pressure upon them, would crush such delicate fibres as those of cotton when it passed between them. The top roller is therefore almost invariably covered with some elastic or yielding material. Usually it is first covered with a specially woven woollen cloth, which is firmly cemented to the iron surface of the roller: this gives a good elastic foundation. Over this is tightly drawn a thin leather covering, which thus forms a smooth, regular, and firm surface, which is capable of gripping the slivers and yet at the same time yielding sufficiently to prevent damage to the fibres. The maintenance of a perfectly round leather-covered roller is of great importance in the draw frame, and under all circumstances it ought to be maintained. One way of doing this has already been indicated in the use of the variable pitch in the flutes of the bottom roller, but this is only applicable whilst the machine is working. When a stoppage of the machine takes place for any length of time, such as a week-end or holidays, the top roller can be damaged considerably by the effect of the hanging weights producing a depression in the yielding material of the top roller. This, when the machine works again, is easily seen in the slightly eccentric running of the roller, and its effect is to produce irregularity in the sliver. In most mills, when a stoppage occurs, the weights are disconnected from the rollers, and this can be done either by going round to each of the weights and uncoupling them separately, which means a great waste of time and energy, or by the use of some system of raising all the weights in one head at once. Such a system is shown in the

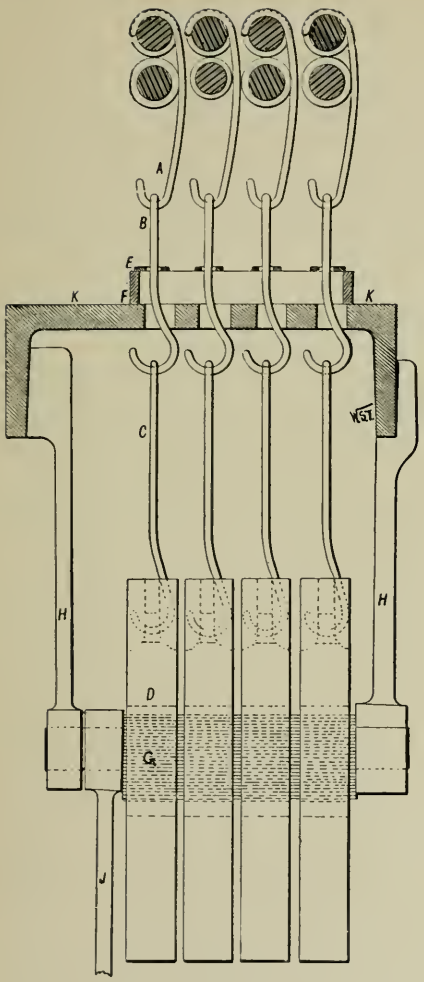


Fig. 5.

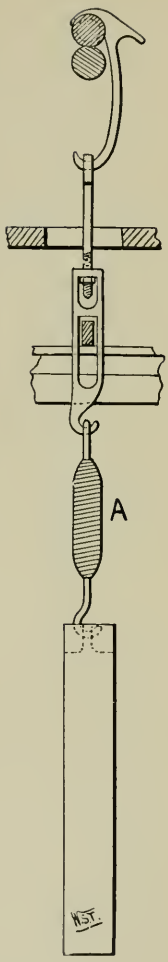


Fig. 6.

accompanying drawing (Fig. 5). The four lines of rollers are shown with the hooks A hanging from the top rollers. To these hooks other hooks B are attached, and to these are connected the weight hooks C, to which the weights D are hung. In each weight is a specially formed hole, through which passes an eccentric G, so as not to touch the weights in any way whilst they hang from the roller. The eccentric is carried at each end by brackets H bolted to the beam. On one end is connected a handle J, conveniently placed for being used when required. A quarter turn of this handle turns the eccentric sufficiently to bring it into contact with the weights on the upper part of the hole, and a slight continuation of the movement will naturally raise them bodily, and so relieve the pressure on the rollers. The elongated cast-iron washer F, together with the small washers E, are used to prevent the hooks B falling through the holes in the beam whenever they are uncoupled from the weight hooks.

A further refinement in weighting is adopted in some mills, and consists in making the hook C in two parts, and placing a spring between them. This has the effect of neutralising any slight shock that might come upon the rollers, its purpose being simply to act as a cushion. Fig. 6 shows a modified form of this system, as made by Brooks and Doxey, and the effect of the spring A is to reduce vibration due to the high speed of the roller.

Loose Boss Rollers.—We have treated of the top roller so far simply as a roller covered with leather and working in slides or bearings at each end. Such a roller is called a solid roller, and is represented in the drawing (Fig. 7). They are, as a rule, used only for the last three lines of rollers. The front line of rollers is now almost invariably made with loose bosses. This type, introduced by Evan

Leigh, is shown in Fig. 7 in section, and from it we see that there is a centre spindle having a barrelled body, over which is fitted an outer shell which runs loose on the centre roller; and since it is only in contact with it at the points A, friction will be considerably reduced. Such a roller can easily be lubricated, the tendency of the oil being to run down to the points A and stop there; the oil is consequently prevented from getting on to the cotton as it passes through. The centre roller does not revolve, so that no lubrication is required on its pivots. It is much easier in

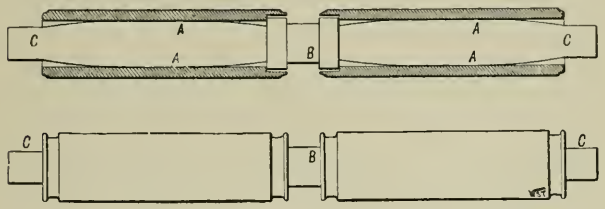


Fig 7.

a roller of this class for the outer shell to revolve over the stationary centre roller, especially when such a thorough lubrication can be obtained; consequently it has become very generally used. In spite of these advantages, however, there are many who still prefer the solid form of roller. It is contended that the very ease with which it revolves is a disadvantage, inasmuch as the grip will be reduced, and to restore it heavier weights must be used. It is also claimed that a better draft can be obtained with a solid roller; but when a practical examination is made of the matter the contentions are found to be of no value whatever. In the facility with which the loose boss roller works there is an advantage that has not yet been mentioned—that is, the

prevention of the possibility of the top roller remaining stationary, if only for a moment, whilst the bottom roller is still running. When such a thing happens the slivers that are passing at the time are practically crushed or very much weakened by the rubbing they receive. This cannot occur with loose boss rollers, and from this fact alone there exists a strong recommendation for their use.

Loose Bush Rollers.—Another form of top roller, which has even greater advantages than the loose boss type, is one in which the roller itself is solid, but each end works in a loose bush; a good surface for lubrication is thus provided, as well as greater facility for the oiling, and friction is almost eliminated. It was formerly the rule to have double boss rollers in the draw-frame, but this practice has fallen almost out of use. Their advantages over single boss rollers was apparent—for instance, there were fewer hooks, wires, and weights, and consequently the cleaning of the machine was a much easier matter and quickly performed; the weighting was also much more simple, the machine was less costly, and in the lubrication less oil was required, this, of course, reducing the probability of staining the slivers. The single boss roller, however, in spite of the above, has one great advantage which the double boss does not possess, viz. each sliver, or group of slivers, is treated by itself, independently of others, so that more regular yarn is produced. In connection with this question of loose bush rollers, one well-known firm (Brooks and Doxeys) writes as follows:—"Where manufacturers prefer double boss rollers we strongly advise the front top roller being made with loose bosses, as these obviate cutting the roller leather arising from one of the bosses being larger than the other to defective covering. For single boss rollers, how-

ever, which have the advantage of only two selvages instead of four, we advise the use of loose bush rollers." A single boss roller would be weighted from each end, and if 16 in. long on the boss, the leather-covered portion would be about 8½ in. long. The double boss roller is weighted from its middle, and the leather-covered portion on each side of the hook would be about 5 in. long.

It is the practice in most mills to have the bottom rollers case-hardened in the necks, whilst in some the whole of the bottom rollers are case-hardened throughout. As a result they are rendered stiffer and stronger, and more capable of resisting torsion, while the flutes are less likely to be damaged either through accident or carelessness.

Diameters and Setting of Rollers.—Some attention will now be paid to the sizes and the conditions of setting the rollers, together with the circumstances that must be taken into account in their arrangement. The importance of the relative position of the rollers to each other, according to the cotton being worked, cannot be overestimated. If the operation is carelessly performed, nothing can afterwards remedy the bad work that is sure to result. There is one broad principle that must always be used as a guide in setting the rollers. The last pair of rollers must be so set that the distance apart of their centres just exceeds the average length of the staple of the cotton passing through. The previous pair of rollers are then set ⅛ in. farther apart than this, and the back pair ⅛ in. farther still, so that if the staple used is 1 in., then the distances would be 1⅛ in. between front and second, 1¼ in. between second and third, and 1⅜ in. between third and back. The above is a good plan to follow, but variation may be introduced and the distances made slightly less, especially where the cotton is soft and not heavy or wiry. The following sketches, with

See Appendix for Drawing and Drafting of Cotton Fibres.

dimensions, will convey a good idea of the arrangement of the rollers and their sizes for different classes of cotton. The dimensions of the top rollers in each case represent the

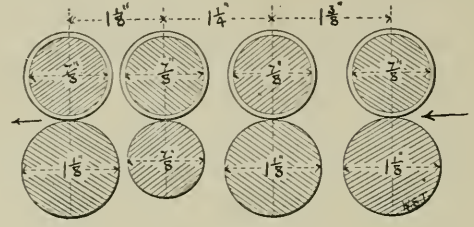


Fig. 8.

diameter before it is covered. Fig. 8 is for Indian cotton, Fig. 9 American cotton, and Fig. 10 Egyptian and Sea Island cotton.[1]

The following summary will represent the main points that are deducible from what has already been said :—The

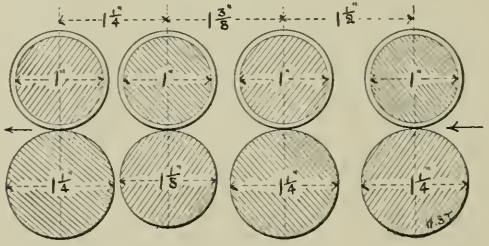


Fig. 9.

short-stapled cottons require small rollers and short distances between them ; as the staple increases in length the rollers must be enlarged and the distances increased. If a heavy sliver is being used, the distances between the centres must

[1] Vol. III. gives more complete details on this subject to which reference may be made.

be greater than when a finer sliver is passing through. If the draft is rather small, or, as it is sometimes called, "easy," and the sliver is fine, the distances between the rollers can be a little less than when the draft is a high one and the sliver heavy. If the staple of the cotton is irregular, the best thing to do is to bring out the roving as fine as possible and use easy drafts. When a big draft is used, the rollers should be run slowly. As the draft is lessened a quicker speed may be run; but it should always

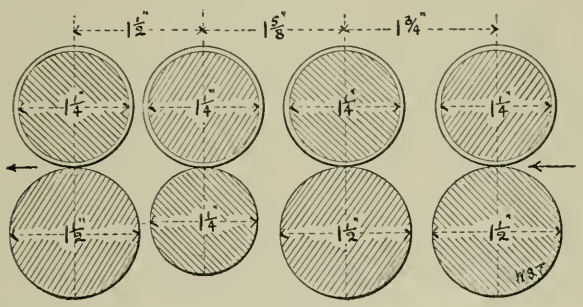


FIG. 10.

be remembered that a large percentage of waste will result if a big draft and a big speed are run together.

Principles of Draft.—Now that we understand the general arrangement of the machine and the disposition of the rollers, it will be beneficial at this point to make an examination of the principles upon which the action of the machine is based. In the draw-frame there are two absolutely distinct operations, each one serving its own purpose, and producing a result totally different from the other. By combining the two operations into one process, we obtain the desired result of parallelisation of the fibres and regularity of the delivered sliver. The two actions will be considered in their order.

NOTE.—See Ch. IV., Supplementary Notes, for drafting of cotton fibres.

It has already been mentioned that the sliver passes through four pairs of rollers, each pair of which, after the first, is accelerated in speed, the result being an attenuation or drawing-out of the fibres. It is advisable to understand this clearly. In the first place, the sliver is fed to the first pair of rollers, which carry it forward; the second pair of rollers now grip the cotton, and since they are revolving at a greater surface speed, they will take the cotton forward quicker than it is being given to them. It will be readily understood that if both pairs of rollers held the same fibres of cotton at the same time the fibres would naturally be broken; it is to prevent this happening that the rollers are set apart a little wider than the length of the fibre. The fibres under these conditions, therefore, yield among themselves under the action of the quicker roller, and in doing so their contact with each other sets up sufficient friction to cause each fibre, as it is pulled along, to straighten itself out into a comparatively level condition. The surrounding fibres are all being acted upon in the same manner, so that although the sliver as a whole is gradually being made thinner, its fibres are also being made to lie in the same direction as the length of the sliver. There is another point that it is as well to understand. By referring to the remarks on the setting of the rollers, it will be noticed that the fibres, when passing from one pair of rollers to another pair, are not immediately gripped, but lie free, as it were, between the two pairs. Such fibres are in reality being drawn in almost the same way as if they were gripped, because their ends are being acted upon by the fibres that are passing through the rollers; in addition, the friction thereby set up carries them forward, and in doing so drags the other ends over the fibres that are being delivered, and so straightens them. The reason why the different pairs of

rollers are not uniform in their distance apart is not far to seek. As the sliver from the card or comber is passed through, the first two pairs of rollers must be wide apart, because the sliver is thickest, and also, for the same reason, the least drawing action must be performed, so as not to damage the fibres, but to act on them gradually; the time of leaving the grip of one pair and being gripped by the next pair must therefore be sufficient to permit of this being done. The sliver is considerably reduced by the time it reaches the last, or, as it is frequently called, the front pair; so here we have the least distance and the greatest draft consistent with good work.

Nothing has been said so far about this attenuating process having the effect of obtaining any species of regularity in the thickness of the sliver, and to a thoughtful reader it is quite obvious that no kind of regularity can possibly be obtained by a purely drawing-out process as it exists in the draw-frame. If a thick and thin sliver were passed through the machine, their relative condition would be practically the same when delivered, no matter what amount of draft be given. As an illustration we will take an exaggerated example of an irregular length of sliver. Suppose we had a length of sliver 2 ft. long, each 6 in. of which had a diameter of 1 in., $\frac{3}{4}$ in., $\frac{1}{2}$ in., and $\frac{1}{4}$ in. respectively, and this were passed through a machine having four of a draft, the result would clearly be that each 6 in. would be lengthened to 2 ft., and the cross section of each sliver would be reduced to one quarter of what it was on entering; we cannot reasonably expect any other result. The fibres would certainly be in a more parallel condition, but the irregularity, so far as thickness is concerned, would still exist, because nothing has been done to lessen it. On the other hand, great irregularities

can be introduced by carelessness in the drafting and weighting of the rollers.

The laying of the fibres in parallel order is a very important duty in the draw-frame; but the equalisation of the sliver is equally important. The process of doubling the slivers enables this condition to be obtained, and it must be repeated as often as is found necessary to obtain the required degree of regularity with the least strain on the fibres. The principle underlying the action was touched upon when dealing with the doubling of the laps in the scutcher (see vol. i.); but here we will go into the matter a little more fully, because it is the very foundation upon which regular yarn is made. If a number of slivers, say six, that may be very irregular in diameter, were placed side by side or made into one thick sliver, it is generally assumed that there would be great probability of the thick and thin places coming together; and the assumption would be a correct one even if it depended only upon experience for its sanction. One may make thousands of tests from the carded sliver, knowing beforehand its variation from regularity, and if six are simply placed together the regularity will be improved. It may and does happen that two, three, or even six thick or thin places come together, but the chances of their doing so are very remote, and do not neutralise the argument that there is an enormously increased probability of greater regularity occurring. We will try to demonstrate this by an example, and whilst taking numbers that are large and give a wide variation, it will readily be understood that, whatever numbers are taken, similar results will be given. Suppose a sliver was very irregular, and its different thicknesses were represented by the numbers 1, 2, 3, 4, 5, and 6. Such a sliver would be six times as thick in one place as in

another. Now take, say, three slivers like this one, and place them side by side, and let us consider the question whether the irregularities will be reduced by so doing. Granted that the irregularities are equally disposed in each sliver, we can see at a glance that there is only one position they can occupy side by side so as to obtain their greatest irregularity, and that is when the thickest and thinnest places all come together; but when we know that the possible combinations of the different thicknesses in the three slivers are innumerable, it is easy to see that the probabilities are all in favour of regularity. A very simple illustration will make this point perfectly clear. A diagram is given in Fig. 11 and portions of three irregular slivers are shown at A, B, and C. Measurements of these slivers were made at seven points in their length, and the figures over each point represent the diameters to scale. It will be noted that greatest difference between the thickest and thinnest place is 12. Similarly the difference in B and C is 8 and 19 respectively. Now if these three slivers are placed together and then drawn out to three times their length we shall obtain a sliver D which is equal to A, B, and C divided by 3. If the diameter numbers on A, B, and C are totalled at each respective line and divided by 3 we obtain the diameter number of the new combined sliver D; and it will be noted that the new diameter numbers only represent a difference between the thickest and thinnest of $6\frac{1}{3}$, so that the new sliver is greatly improved in regularity upon each of the original three slivers composing it. If more slivers are combined the probabilities increase, and when we consider that irregularities in a sliver are also very irregular in their position along the sliver, we increase still more the chances in favour of regularity. Upon all this, the fact should be considered, that when six slivers

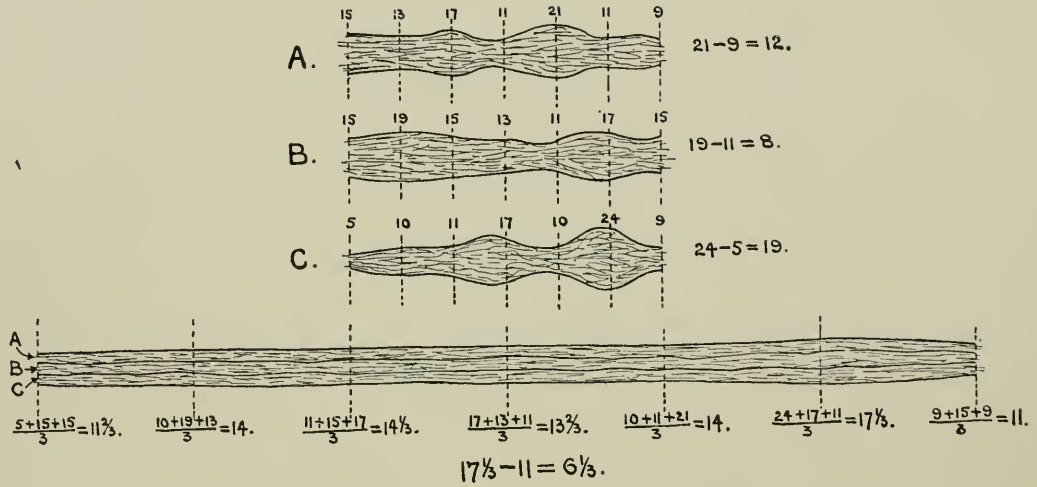

A.
15 13 17 11 21 11 9
21−9 = 12.
B.
15 19 15 13 11 17 15
19−11 = 8.
C.
5 10 11 17 10 24 9
24−5 = 19.
A
B
C
5+15+15/3 = 11⅔.
10+19+13/3 = 14.
11+15+17/3 = 14⅓.
17+13+11/3 = 13⅔.
10+11+21/3 = 14.
24+17+11/3 = 17⅓.
9+15+9/3 = 11.
17⅓ − 11 = 6⅓.

Fig. 11.

are put through the draw-frame, six of the resulting slivers are passed through another head, and six slivers that are the result of the second drawing are passed through a third time. Each time they have been submitted to a draft of six, so that the total doubling the sliver has received is $6 \times 6 \times 6 = 216$. The diagram in Fig. 12 will

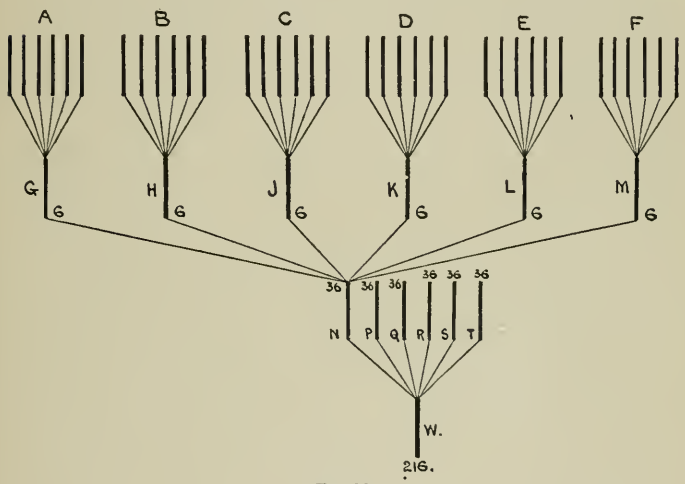


FIG. 12.

perhaps make this clear. A represents six card slivers, and they are doubled, drawn out, and form one sliver at G. A similar thing happens at B, C, D, E, and F, and results in single slivers at H, J, K, L, and M. The six slivers G, H, J, K, L, and M are doubled and drawn out to one at N, so that N is the result of 36 original card slivers being doubled together. Each of the slivers P, Q, R, S, and T also represents 36 original card slivers, so that if these six slivers N, P, Q, R, S, and T are doubled together, the resulting sliver W is the result of doubling 216 original card

slivers. We can thus easily realise that in the operation of doubling we have a process upon which every reliance can be placed in obtaining regularity of the sliver, and that the principles upon which it depends are perfectly sound.

Stop Motions.—It is quite manifest that the value of doubling will depend very much for its success upon the continuous feeding to the rollers of the same number of slivers. If six slivers are fed this number must be maintained, for

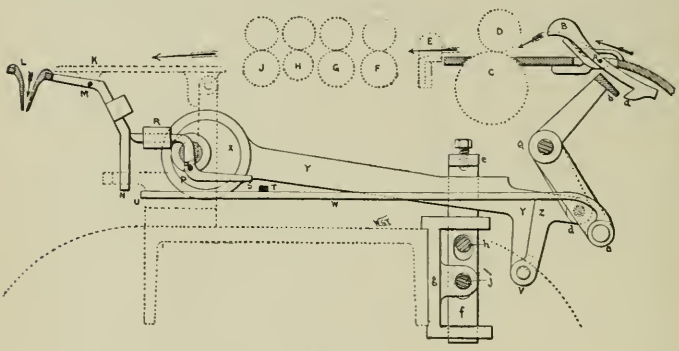


FIG. 13.

if one of them broke, and it was not immediately pieced up, there would be a weak spot in the delivered sliver of over 16 per cent less than the adjacent portions; so it is imperative that this should be avoided, and consequently in all draw-frames means are taken both at the front and back of the machine to prevent the possibility of such a thing happening. A variety of mechanical methods are employed to serve this purpose, one or two of which will now be given. Fig. 13 shows the first example. After the slivers have passed through the sliver plate from the cans, each one is conveyed over a lever B, centred on a pivot at A.

The upper portion is formed as a kind of spoon, so shaped as to keep the sliver in position, and the lower part is made with a hook-shaped projection "a." The spoon lever B is so pivoted as to be almost balanced. Its heavier portion is, however, at the bottom. When a sliver is passed over the spoon there is sufficient weight, together with the tension in it, to counteract this weight and cause the upper portion B to be depressed; and so long as a sliver is going forward or its tension is maintained, the lever

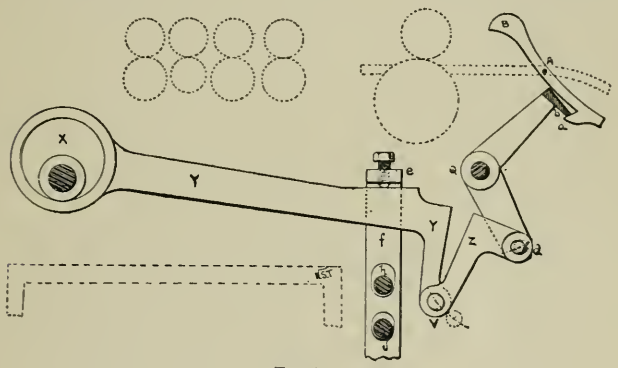


FIG. 14.

will always occupy the position shown in the drawing (Fig. 13). Directly an end breaks, through a knotted portion not being able to pass through the sliver plate, and also in consequence of weak spots existing in the sliver, or when a can runs empty, the upper part is relieved of its weight and the lower portion "a" immediately falls, and in doing so occupies a position which prevents a vibrating arm "b" from working. This causes almost instantly the stoppage of the machine. Its precise action is worthy of a detailed examination, so, although the sketch (Fig. 14) is similar to the drawing (Fig. 13), it is reproduced here stripped of the

accessories, and the stop motion only shown distinctly. An eccentric X, acting through the arm Y and the bell lever on the shaft Q, gives to the vibrating knife "b" its reciprocating motion. Under normal conditions of working "b" passes through a short arc of a circle, and in doing so just misses the hook portion "a" of the spoon lever. It will be noticed that the eccentric arm Y is in two parts, Y and Z, and that they are connected by a pin at the centre V. The end "d" is in connection with the vibrating lever working on the shaft Q. The whole arrangement is so balanced as to offer very little resistance to the free movement of the two portions of the eccentric arm, and it therefore works as if it were one piece. If anything, however, interferes with this freedom of movement—for instance, when an end breaks and the hook part "a" of the spoon lever B drops and prevents the motion of "b"—something must yield, for the eccentric continues to work. This yielding takes place between the two parts of the eccentric arm, and results in the lifting up of Y bodily. In this action it is brought into contact with the upper portion "e" of a knocking-off slide "f," which keeps the strap on the fast pulley. As "f" is lifted up, the shaft J, which is kept in position by the slide, is released, and a strong compression spring placed upon it, acts through suitable stops, on the strap-fork rod "h," and so changes the strap from the fast to the loose pulley, which stops the frame. The machine cannot be started again until the cause of stoppage is put right. Fig. 14 is given to represent the position occupied by the eccentric and levers when an end breaks. The eccentric is in its highest position, whilst the centre V has also been raised from its normal position. This clearly lifts up the arm Y, and when this is effected the stoppage of the machine is a comparatively

simple matter. This motion is generally called the **Back-stop** motion.

There is also in front of the machine another stop motion, its object being to prevent a decreased number of slivers passing through to the coiler. This reduction in the sliver may occur either through breakage or roller laps, *i.e.* when a sliver sticks to the leather of the roller and begins to be wound round it. Crossed and knotted portions may occur, and these also stop the machine. The slivers coming from the front roller pass over the plate K (Figs. 1 and 13) and down through the funnel L into the coiler can. The funnel L is carried by a lever centred at M, and is so balanced that any diminution of tension of the slivers will cause the funnel to lift up, which causes the other end N to fall, and in doing so it comes in the way of a vibrating feeder bar W. This bar is connected with the eccentric arm, and is actuated from it. Directly, therefore, that its motion is stopped, the two portions Y and Z separate, as in the back motion, and the frame stops. If from any cause too much sliver is going through the funnel L, it will do so with difficulty and naturally depress it. This depression raises one end R of a lever, which is centred at P, and depresses the end S. A stop pin T on the vibrating feeder bar is by this means prevented from passing forward, and as a consequence its movement is stopped, and, through its connection, the machine also. The position of the weight R on the lever is used to regulate the amount of sliver that can be passed through the funnel without stopping the frame.

Another form of stop motion, made by John Hetherington and Sons, is shown in Fig. 15; enlarged views are also given of some of the details. The action is as follows:— The sliver passes forward from the cans in the direction of

the arrow, and is guided to the "single preventer" rollers G and H by the guide J. From here it moves towards the rollers over the spoon F; through this spoon, means are adopted for stopping the machine when an end breaks or a can runs empty; the enlarged view will enable the action to be understood. As the sliver goes forward, the spoon F, fulcrumed on the knife edge O′, is pressed down upon the

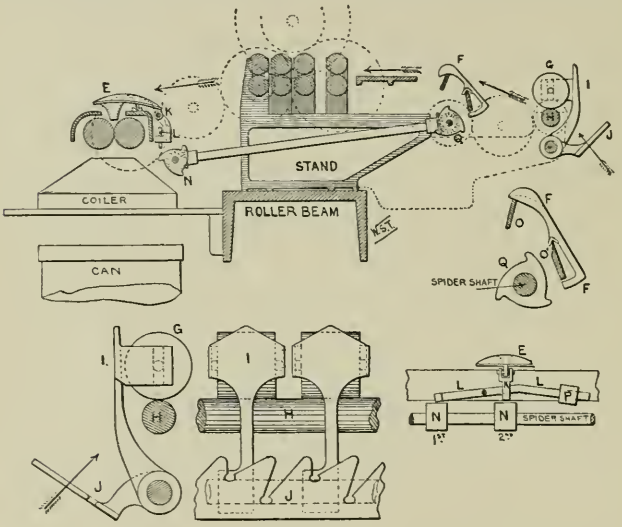


FIG. 15.

rod O, and in this position its other end is kept out of the way of a revolving spider Q. If an end breaks, however, the pressure is taken from the spoon, and its lower end, being the heavier, falls and comes into contact with the revolving spider Q; through inclines on the face of the spider a sliding motion is produced which, actuating a stop rod, moves the strap on to the loose pulley, and so stops the machine.

The front stop motion acts as follows:—The sliver passes through a funnel E which is pivoted as shown in the drawing. It is balanced by means of the weight P, and this can be so carefully done that if too thick or too thin a sliver is passing through, the funnel will fall or rise. For instance, if a knot or twisted sliver tries to go through it will depress the funnel, this will raise the link K and so act on the lever L (see enlarged drawing) as to bring one end of it into contact with the 1st spider N and stop the machine. On the other hand, if too thin a sliver passes through, the link K will fall and come into contact with the 2nd spider and also stop the machine.

It is very desirable, whenever an end breaks, that the piecing should be a direct one. It is not sufficient that the two ends are placed just in contact; there must be no interval whatever between the two. The fibres of one end must interlock with the fibres of the end to which it is pieced. To do this effectually we must arrange the machine so that the breakages occur at points where the piecings can be performed successfully, and with a minimum of trouble. If a breakage of sliver happened just as it was entering the rollers there would be considerable difficulty and loss of time, as well as waste, in making a successful piecing; so, to prevent this, all draw-frames are now made with what is generally termed a "single preventer" motion. This usually consists of two rollers (see Figs. 1, 13, 14, and 15) placed between the sliver plate and the spoon levers. The bottom roller is driven at a slightly slower speed than the back roller, so that the sliver between them has a small draft and is in tension. Any breakage that occurs will almost invariably be between these rollers and the cans, so that immediately the broken end passes between the two rollers the spoon is relieved and the machine stops.

The piecing at this point is easily effected. The stop motion also acts much quicker with the single preventer. The tension of the sliver between it and the back roller is always uniform, and is sufficient to keep the spoons in their correct position, as they act instantly when the tension is removed. Without this motion the tension would be very irregular, since the sliver coming from the can would one moment be tight and the next very slack, and formerly it was no uncommon thing for the machine to stop simply because of slack sliver.

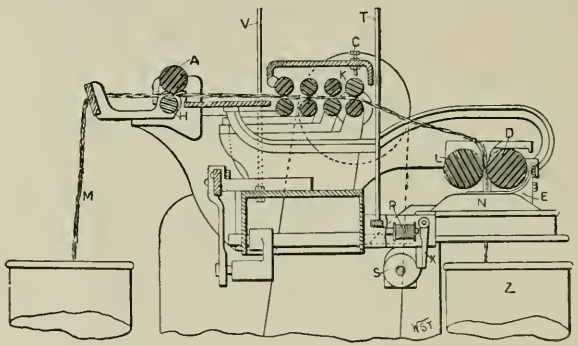


FIG. 16.

Owing to the multiplicity of parts and the separate motions necessary to obtain thorough control of the machine by means of the mechanical arrangements just described, a large firm of machine-makers, Howard and Bullough, introduced several years ago a method of attaining the same, or even better results, by means of electricity. In order to understand the question fully, a drawing of a section of the draw-frame is given in Fig. 16. Here the sliver is shown in its passage through the machine, and it is quite apparent that the whole arrangement is of the

most simple character. The principle upon which the action of the machine relies for its effective working is based upon the important fact that cotton is a very good insulator, or, in other words, a non-conductor of electricity. Electricity, generated by means of cells placed near the machine or wherever desirable, is conducted by wires to certain parts of the frame. This electricity is rendered inoperative so long as the opposite poles of the current are not allowed to be brought into contact with each other. Directly one part of the machine having positive electricity is connected to another part having a negative current, the current begins to circulate, and if means are taken to introduce in the path of the current some appliance like the electro-magnet, the machine can be readily stopped by its action upon catches or otherwise. In the drawing the single preventer motion is shown at AH. The bottom roller is continuous, and is supplied by electricity from one pole of the battery. The top rollers are in short lengths, each length having two slivers passing under it. They are connected to the opposite pole of the battery, and insulated from the rest of the machine. So long as the top and bottom rollers are kept apart by the slivers which pass between them nothing will happen, because the current is disconnected, and therefore powerless; but immediately a sliver breaks, the rollers come into contact, and the current begins to flow through the electro-magnet P. This, as a consequence, is made sufficiently powerful to draw on one side a hanging catch X, which is thus brought into the path of a revolving cam S. The motion of the cam is stopped by this action, and, in stopping, it actuates the strap shifter in such a manner as to stop the machine. When the sliver breaks in front of the frame, after passing through the rollers, the stop motion is arranged to be actuated from

the calender rollers L and D. These are insulated in a similar manner to the back roller motion A and H, and the slivers in passing between them prevent the flow of the current; but when a breakage does occur the rollers come together, and the machine is instantly stopped by the same electro-magnet and catch as in the first case. When the sliver wraps round the roller, either top or bottom, its immediate effect is to lift up the top roller. This completes the circuit by bringing roller K into electrical contact with the top clearer at the adjusting screw C, and so puts into operation the electro-magnet P. A similar result happens when the can is full. In this case the machine is stopped through the excessive pressure of the sliver in the can lifting the tube wheel slightly, and thus connecting the two poles of the battery.

Whatever may be said against the introduction of electricity into a room which, in the majority of cases, is already greatly charged with the fluid in a most inconvenient and unmanageable form, its results in the attainment of the desired ends that necessitated its introduction have caused it to be held in high repute by all who have had occasion to use it.

Top Clearers.—We now come to another detail of the draw-frame, viz. the top clearers, and they are an essentially important feature of it. Owing to the large amount of friction that is set up in a cotton mill, and the practically complete insulation of the whole ironwork in the building, the electricity that is generated is gradually accumulated until its effect on the various machines and the fibres of cotton is to tend to draw them away, with the result that these fibres cause a wiriness to appear which, unless suitable

humidifying influences are brought to bear on it, will continue in the subsequent stages. In the draw-frame the slivers are untwisted and relatively parallel to each other, so that this effect of electricity is seen in the ease with which the fibres attach themselves to the rollers and are carried round. If this continues for some time the loose fibres will accumulate, and eventually, by gravity or other disturbing force, fall back on the slivers and be incorporated in them, to their considerable detriment. It is, therefore, necessary to clear the rollers by some continuous process, so that as little labour as possible is introduced into the operation. One method of doing this is by means of what is termed a stationary flat. A sketch of this form is shown in the section of the draw-frame in Fig. 1. It consists of a piece of flannel attached at the front and back to a portion of wood in such a manner that the weight of both wood and flannel rests on the top rollers. The roughness of the flannel naturally clears the rollers of the loose fibres and particles of dirt that may adhere to them. In the arrangement there are no means taken to carry away what is generally called the flat waste, so it gathers into lumps, and at last will drop into the slivers unless great care is taken in cleaning them at regular intervals of about two hours. To avoid this unnecessary labour, and the probable spoiling of the cotton, several good types of top clearers have recently been introduced, which minimise to a very large extent the inconveniences associated with the stationary flat. A typical form, made by Dobson and Barlow, is given in the accompanying drawing (Fig. 17). It consists essentially of two wooden rollers covered with flannel, one of which rests between the front and second rollers, and is driven positively at such a speed as to prevent any damage to the leather rollers upon which it rests, and

yet so that it can clear them of their adhering fibres. The other roller simply rests between the third and back rollers. This roller will receive a turning motion, due to the fact that it is in contact with two rollers that are running at different speeds. The friction set up between them clears the leather. It is quite obvious that the revolution of the two clearer rollers will, in addition to their cleansing action, also form around themselves in a kind of lap all the dirty and loose cotton they collect. There can, therefore,

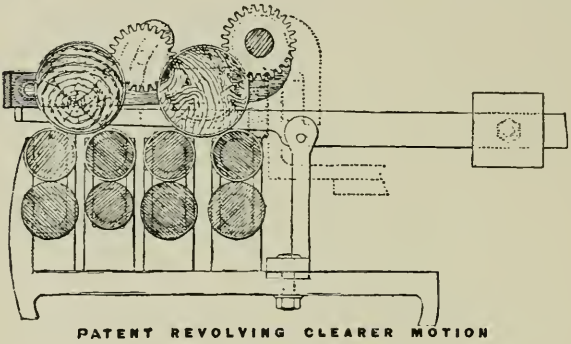


FIG. 17.

be no accumulations with their attendant evils. The stripping of the roller is an easy matter, and only requires to be performed about once a week. This is a decided improvement upon the frequency of stripping which was necessary in the earlier form noted above. It will be noticed that the weight of the flannel-covered rollers must be carefully adjusted, for it is bad policy to allow the full weight of any arrangement, unless it is very light, to rest indiscriminately upon the top rollers. The requisite arrangement in the apparatus is attained by the employment of a balanced lever, pivoted as shown, one end of which

rests under the frame carrying the rollers, whilst the other end is weighted with a movable weight. By this means the pressure required on the rollers is readily obtained.

Two other examples of clearers are given in Figs. 18 and 19. Fig. 18 consists of a flannel A carried over rollers and driven positively; the friction of the flannel on the top rollers gives a cleansing action. The flannel is automatically cleaned by means of a reciprocating knife B resting on the flannel and being carried by an arm C centred at the end D of a lever carried on a stud at E. An eccentric gives to the end F a to-and-fro movement which is transferred to the knife B, and which enables the knife to scrape

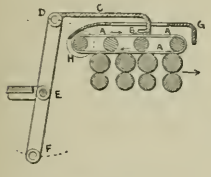


FIG. 18.

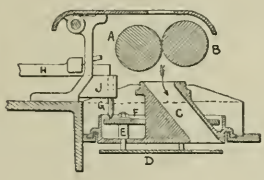


FIG. 20.

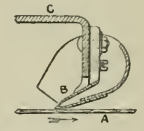


FIG. 19.

off the fibres, etc., collected by the flannel. This clearer is generally known as Ermen's Clearer. An improvement on it, known as Colling's Clearer, is shown at Fig. 19; the arm C has a double knife B, the fly and dirt scraped off the flannel A is collected in the receptacle shown, and thus prevented from escaping and falling down on to the emerging slivers.

Full Can Stop Motion.—Fig. 20 represents a full can stop motion: it is very simple in principle and quite effective. As the can fills, the sliver presses upwards against the plate D, and this moves a plate F also upwards. In contact with the plate F is a pin G, which is forced up until it comes into the path of a reciprocating rod H which

it stops, and this stoppage, through the usual means, leads to the stoppage of the machine.

A full can stop motion is also made which acts when a certain length of sliver has been put into the can; a worm and worm wheel, actuated from the rollers, cause a stop-piece to move forward on a screw until eventually it comes into the path of the reciprocating rod through which the stop motion acts.

Metallic Rollers.—As their name implies, these rollers are of metal and intended to displace the top leather-covered rollers of Draw and Fly frames. They are fluted and spaced in such a manner that they practically gear with the bottom rollers, so that as the sliver passes between the two it receives a crimping effect. Claims are made that this is an advantage and adds to the elasticity of the yarn, but it is an extremely doubtful advantage even where it exists. A further claim made is that an increased production is obtained from the same speed of roller. This may be considered. In the first place the increased length delivered, due to the crimping, implies an increased speed of spindle, in order to put in the desired twists per inch. Moreover, because of the increased length, the draft must be regulated by running the back roller at a higher speed. These are two palpable results to be taken into account if a comparison is to be made between a machine working with and without metallic rollers. The question of their advantage in higher production may therefore be considered as a very small matter and of no practical value in a mill. It has also been found that the passage of the sliver between the flutes has a crushing effect on the fibres, though this has been modified in the most recent form of roller. The older form of metallic rollers simply consisted in the flutes, of the top roller resting in the spaces of the

bottom roller. The next improvement was to prevent this by turning collars on each end of top and bottom rollers; these were of such a size that when the collars were in contact, the tops of the flutes of one roller did not come into contact with the bottom of the spaces of the other roller. This, however, did not prevent the crushing effect, so a further improvement was to cut at each end of each roller flutes and spaces that rested on and in each other; but in the middle part of the roller, through which the sliver passed, a less diameter with smaller flutes and larger spaces was made; this naturally is the best form of the arrangement.

A section of Asa Lees' draw-frame is given in Fig. 21, and whilst it follows the usual design the *stop motions* are sufficiently interesting to be illustrated and described. The motion shown in the drawing is driven from the coiler shaft to a wheel on which is cast an eccentric A, on which fits the strap B, with its rod C weighted at D, with an extension on which is fixed a stud E. This stud E enters a V-shaped slot in the lever F, whose fulcrum is at C; the other end of lever F is extended to I. The weight D maintains the stud E at the bottom of the V slot, and the lever F will simply oscillate to and fro freely. If the end S of the spoon or the end of the trumpet lever H comes into the path of the vibrating ends I or J, then the V-shaped end of F will be locked, and the stud E, being free to move, will slide up one of the grooves in the V, and on coming into contact with the arm K move its other arm out of the locking position on the stop rod L, and so stop the machine.

In Fig. 22 we have Dobson and Barlow's improved design of the machine illustrated in Fig. 1. It will be noticed that the rollers D, C take up the slivers from the cans and that the single preventer is placed between these

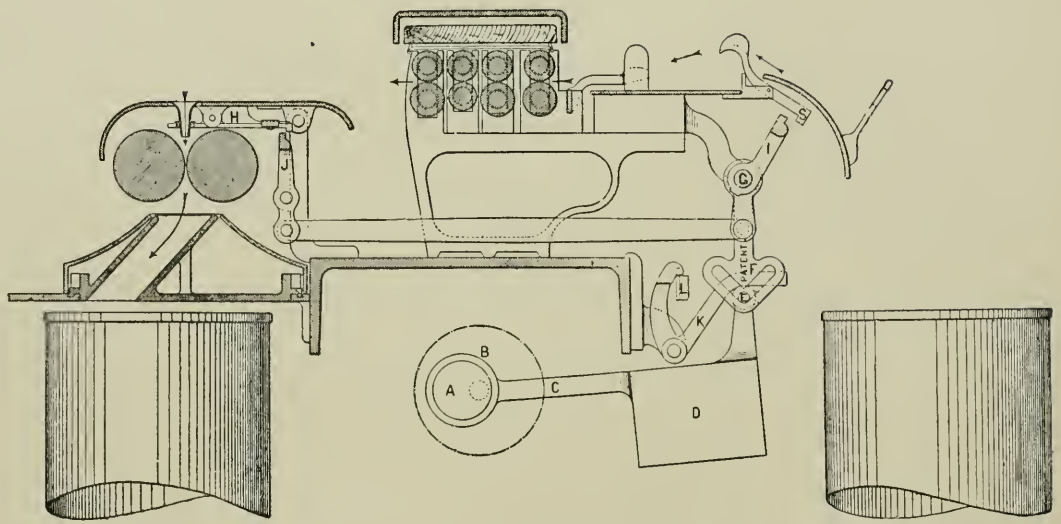


Fig. 21.

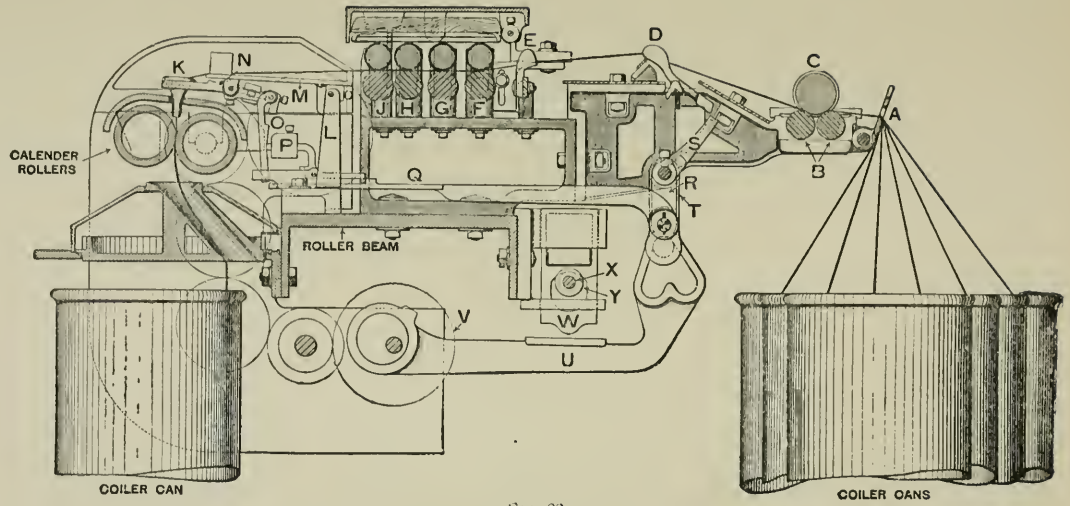

CALENDER ROLLERS
ROLLER BEAM
COILER CAN
COILER CANS
A
B
C
D
E
F
G
H
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y

FIG. 22.

rollers and the back roller F. Every sliver is thus treated alike and all have equal tension, so that a more sensitive action is introduced on the spoon B, and the trouble caused by mere slackness of the sliver in the cans is no longer a source of annoyance through stoppage of the frame.

Calculations.[1]—We now come to deal with the question of gearing, and the changes to be made in order to obtain the necessary productions and conditions for the purpose in view. A special drawing (Fig. 23) has been prepared, showing at a glance the arrangement of wheels and parts that constitute the chief features of the frame. Whilst mentioning that the machine represented is the method adopted by a leading firm of machine makers, Dobson and Barlow, it is almost unnecessary to point out that other makers' designs vary so little from it that readers can very readily adapt the following calculations to suit the gearing of the machines with which they are directly in touch.

The driving pulley shown on the outside of the frame end receives its motion from a line shaft above. The size of this driving pulley, of course, varies according to the speed required and pulley on the line shaft, but under ordinary conditions an 18 in. × 13 in. will be found a good standard to adopt, although 21 in. is frequently used. On the driving shaft, just inside the framing, is keyed the inside driving pulley B, or, as it is sometimes called, the bottom shaft pulley. In different makes of machines this pulley varies, but for our present purpose 16 in. will be taken as its diameter; it drives, by means of a belt, a pulley C on the front roller, whose diameter as shown is 12 in. From this point the driving of the whole frame takes place, and it is here where the machine is stopped and started,

[1] Full calculations and drawings of the chief machine-makers' draw-frames are given in the author's book *Cotton Spinning Calculations*.

a fast and loose pulley being used for that purpose. The

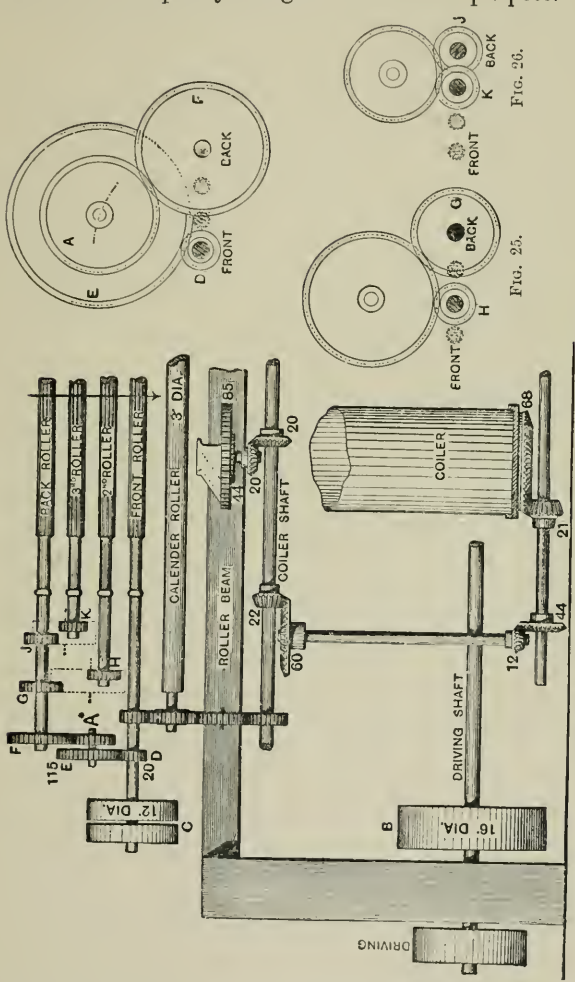


Fig. 23. GEARING OF DRAW FRAME

Fig. 24.

Fig. 25.

Fig. 26.

front roller receives its motion direct from here, the other portion of the draw-frame receiving motion through the

gearing as represented in the sketch The front roller drives the back roller, through D, a compound carrier A E, and the wheel F; the second roller is driven from the back roller through the wheels G and H, a single carrier coming between them to preserve the direction of revolution; the back roller also drives the third roller by the wheels J and K, a carrier again being necessary here to turn the roller in the right direction. The system shown is the one generally adopted now, but in some makes of machines the two intermediate rollers will be found driven at the other end of the frame, ostensibly with the object of reducing any tendency to twisting, or at least of neutralising it somewhat; but this is too palpable a fallacy to need explanation, and in all the best or newest designed machines the arrangement shown in the drawing is adopted. The calender rollers are driven from the front roller by a train of wheels whose continuation also drives the top coiler shaft. This shaft, through pairs of bevel wheels, drives each coiler top, whilst it is also the means of conveying motion through bevels to the bottom coiler shaft, from which the coiler can itself is turned. Elevations of the roller gearing are given in Figs. 24, 25, and 26, by which their disposition is clearly shown. To facilitate making the calculation, and putting to a practical test the rules that are given, the following table of particulars is presented :—

A Draft wheel	Various, 40 to 90 teeth.
B Inside driving pulley	Various dias., say 14 in.
C Front roller pulley	12 in. dia.
D Front roller wheel	20 teeth.
E Crown wheel on top carrier	115 ,,
F Back roller wheel	Various, say 80 ,,
G Back roller wheel driving second roller	,, 45 ,,
H Second roller wheel	,, 20 ,,
J Back roller wheel driving third roller	,, 26 ,,
K Third roller wheel	,, 21 ,,
Diameter of front roller	$1\frac{1}{2}$ in.
,, second roller	$1\frac{1}{4}$,,

Diameter of third roller	$1\frac{1}{2}$ in.
,, fourth roller	$1\frac{1}{2}$,,
No. of slivers per delivery	8 ,,
Speed of front roller per minute	264 revs.

Obtaining the correct draft is the most important calculation of the draw-frame, and this is done in the usual way by finding the surface speed of the rollers and dividing the slowest into the quickest, which gives a ratio or number that represents the draft. The front roller has the quickest speed, whilst the back roller runs the slowest, so if we find their respective surface speeds the question becomes an easy one.

(1) Draft between front and back rollers $= \frac{\text{E} \times \text{F} \times \text{dia. of front roller}}{\text{D} \times \text{A} \times \text{dia of back roller}}$

$$= \frac{115 \times 80 \times 1\frac{1}{2}}{20 \times 58 \times 1\frac{1}{2}} = 7{\cdot}93.$$

It will be seen that this formula is made by simply considering the back roller as the driver and working back to the front roller. In most cases this is the best plan to adopt.

When the draft is already given or supposed, and it is required to find the necessary wheel, the same rule is applicable by substituting the required draft in place of the wheel A, as this is the change place.

(2) Change or draft wheel $\text{A} = \frac{\text{F} \times \text{E} \times \text{dia. of front roller}}{\text{Draft} \times \text{D} \times \text{dia. of back roller}}$

$$= \frac{80 \times 115 \times 1\frac{1}{2} \text{ in.}}{8 \times 20 \times 1\frac{1}{2} \text{ in.}} = 57{\cdot}5 \text{ teeth.}$$

For this result we take the next highest wheel, viz. 58 teeth. In order to save repetition of the above calculation, finding the "constant number" is advisable. This is done by using the above rule, but leaving out the draft, or, in No. 1, by leaving out the draft wheel.

(3) Constant number $= \frac{\text{F} \times \text{E} \times \text{dia. of front roller}}{\text{D} \times \text{dia. of back roller}}$

$$= \frac{80 \times 115 \times 1\frac{1}{2} \text{ in.}}{20 \times 1\frac{1}{2} \text{ in.}} = 460.$$

From this constant number we can obtain either the draft or the draft wheel as follows :—

(4) $$\text{Draft} = \frac{\text{Constant number}}{\text{Draft wheel}}.$$

(5) $$\text{Draft wheel} = \frac{\text{Constant number}}{\text{Draft}}.$$

(6) Draft between first and second rollers $$= \frac{H \times F \times E \times \text{dia. of front roller}}{G \times A \times D \times \text{dia. of second roller}} = \frac{20 \times 80 \times 115 \times 1{\cdot}5 \text{ in.}}{45 \times 58 \times 20 \times 1{\cdot}25 \text{ in.}} = 4{\cdot}23.$$

(7) Draft between the second and back $$= \frac{G \times \text{dia. of second roller}}{H \times \text{dia. of back roller}} = \frac{45 \times 1\frac{1}{4} \text{ in.}}{20 \times 1\frac{1}{2} \text{ in.}} = 1{\cdot}87.$$

(8) Draft between the third and back $$= \frac{J \times \text{dia. of third roller}}{K \times \text{dia. of back roller}} = \frac{26 \times 1\frac{1}{2} \text{ in.}}{21 \times 1\frac{1}{2} \text{ in.}} = 1{\cdot}238.$$

(9) Draft between the second and third rollers $$= \frac{K \times G \times \text{dia. of second roller}}{J \times H \times \text{dia. of third roller}} = \frac{21 \times 45 \times 1\frac{1}{4} \text{ in.}}{26 \times 20 \times 1\frac{1}{2} \text{ in.}} = 1{\cdot}56.$$

(10) Production in 10 hours is found as follows :—

$$\frac{\text{Min. in 10 hrs.} \times \text{revs. of F.R.} \times \text{circumference of F.R.} \times \text{grains per yard of sliver}}{36 \text{ in.} \times 7000 \text{ grains}}.$$

(11) The "constant" number for production may be obtained for any diameter of front roller by using rule No. 10, but leaving out the grains per yard of sliver. When this is done the production is found as follows :—Constant number × grains per yard of sliver = production.

(12) $$\text{Weight of drawing} = \frac{\text{number of ends} \times \text{weight of carding}}{\text{draft}}.$$

(13) The draft can be found by the following rule :—

$$\frac{\text{number of ends put up} \times \text{weight of carding}}{\text{weight of drawing}}.$$

(14) The draft wheel can also be found by the proportionate method :—

$$\text{Draft wheel} = \frac{\text{required weight} \times \text{draft wheel on}}{\text{present weight}}.$$

(15) $$\text{Draft wheel} = \frac{\text{present hank} \times \text{draft wheel on}}{\text{required hank}}.$$

(16) The draft between the first and second × draft between the second and third × the draft between the third and fourth = total draft of the machine.

The horse-power required for driving the draw-frame is generally put down as 1 i.h.p. for 12 deliveries.

Draft.—On referring to rule (1) on page 41, it will be noticed that, although we are asked to consider the back

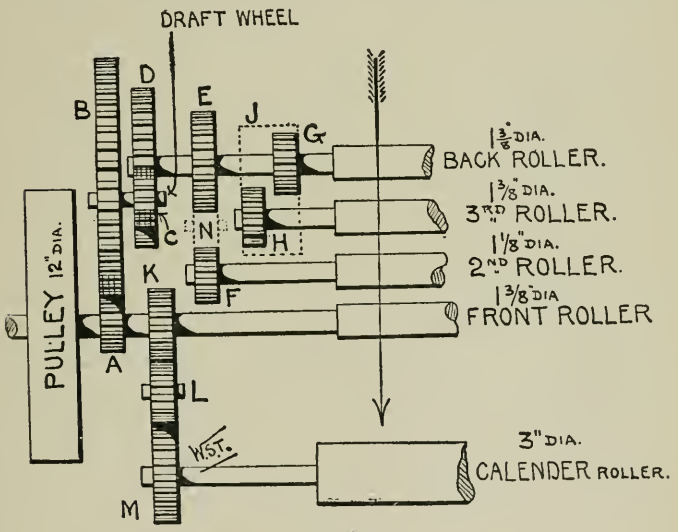


FIG. 27.

roller as the driver, we place the back roller among the driven wheels and the front roller among the drivers. This is puzzling to the student, so an attempt will be made to explain it.

Consider the gearing of Brooks and Doxey's draw-frame in Fig. 27, having the following particulars :—

Wheel	A	20 T.	drives	B	100 T.	Wheels N, J, and L are carriers and are not used in the calculations.
,,	C	40/70 T.	,,	D	70 T.	
,,	E	43 T.	,,	F	16 T.	
,,	G	22 T.	,,	H	18 T.	
,,	K	22 T.	,,	M	48 T.	

The diameters of the rollers are stated on the drawing. Since draft simply means dividing the surface speed of one roller into the surface speed of another roller, we must find the surface speed of the front roller and divide it by the surface speed of the back roller.

Now suppose the front roller has 200 revs. per min., its surface speed will be

$$350 \times 1\tfrac{3}{8} \times \tfrac{22}{7} = \frac{350 \times 11 \times 22}{8 \times 7} = 1512 \text{ inches per min.}$$

The surface speed of the back roller will be

$$\frac{350 \times A \times C \times \text{circ. of B.R.}}{B \times D} = \frac{350 \times 20 \times 58 \times 1\tfrac{3}{8} \times \tfrac{22}{7}}{100 \times 70}$$

$$= \frac{350 \times 20 \times 58 \times 11 \times 22}{100 \times 70} = 250 \text{ inches per min.}$$

$$\frac{\text{Surface speed of F.R.}}{\text{Surface speed of B.R.}} = \text{Draft}$$

$$= \frac{1512}{250} = 6{\cdot}04 \text{ total draft.}$$

We see from this that if we start our draft calculation from the back roller the front roller diameter must be on the top line and the back roller below. If we simply combine the two calculations into one we do so as follows :—

$$350 \times 1\tfrac{3}{8} \times \tfrac{22}{7} \div \frac{350 \times 20 \times 58 \times 1\tfrac{3}{8} \times \tfrac{22}{7}}{100 \times 70}$$

$$= \frac{350 \times 11 \times 22}{8 \times 7} \div \frac{350 \times 20 \times 58 \times 11 \times 22}{100 \times 70 \times 8 \times 7}$$

$$= \frac{350 \times 11 \times 22 \times 100 \times 70 \times 8 \times 7}{8 \times 7 \times 350 \times 20 \times 58 \times 11 \times 22}$$

$$= \frac{50 \times 7}{58} = 6{\cdot}03 \text{ total draft.}$$

If, in this last calculation, letters are used instead of figures, and using only the diameters of the rollers, we obtain—

$$\text{Dia. of F.R.} \div \frac{A \times C \times \text{dia. of B.R.}}{B \times D} = \text{Draft}$$

$$= \frac{\text{Dia. of F.R.} \times B \times D}{\text{Dia. of B.R.} \times A \times C} = \text{Draft.}$$

It will thus be seen that a simple form of reasoning easily explains why the front and back roller diameters occupy the positions they do in rules for draft. The driving of the rollers of the draw-frame is not always the same. Several systems are adopted by machine-makers.

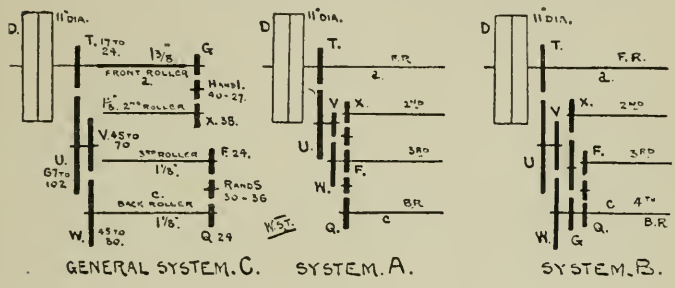


FIG. 28.

For instance, Howard and Bullough's have the three systems shown in Fig. 28. The calculations for these systems all follow on the same lines as the examples already given, so it is unnecessary to work them out here.

[TABLE

Production of Draw Frame.

Dia. of F.R.	Hours worked by frame out of 56½.	Revs. of F.R. per minute.	Weight of sliver per yd. in grains.	Hank of sliver.	Lbs. per delivery in 56½ hrs.	Lbs. per delivery in 10 hrs.	Nos. of yarn and kind of cotton.
1⅛	46	400	66	·126	1020	180·5	10s to 20s China or Indian.
1⅛	46	400	60	·138	928	164·2	
1¼	46	350	60	·138	897	158·7	20s to 24s Indian or American.
1¼	46	350	54	·154	807	142·8	24s to 32s American.
1¼	46	350	48	·173	717	126·9	32s to 40s American.
1⅜	46	300	48	·173	679	120·2	32s to 40s American or Low Egyptian.
1⅜	46	300	44	·189	623	110·2	
1⅜	46	300	40	·208	565	100	
1½	46	280	48	·173	692	122·4	30s to 40s Egyptian.
1½	46	280	44	·189	634	112·2	40s to 45s ,,
1½	46	280	40	·208	577	102·1	45s to 50s ,,
1½	46	250	40	·208	515	91·1	60s ,,
1½	46	250	36	·231	463	81·9	70s ,,
1½	46	200	40	·208	411	72·7	80s ,,
1½	46	200	36	·231	370	65·5	90s ,,
1½	46	200	30	·277	308	64·5	100s ,,

The following table may also be a guide for production in American cotton :—

Dia. of roller	1⅜	1⅜	1⅜	1⅜
Speed of roller	320	350	380	400
Hank of card sliver	·15	·15	·15	·15
Draft	6	6	6	6
Production in lbs. per finished delivery	865	980	1030	1080

CHAPTER II

COMBING

Object of Combing. — It is advisable, now that the subject of combing has been reached, to explain clearly the position this process occupies in the cotton-spinning industry, and also to give the reasons why the treatment of the operation has been placed after drawing instead of after carding, which is the plan usually adopted by textile writers. The explanation necessitates a consideration of several important matters, a knowledge of which is almost essential in order to gain a clear understanding of much that will follow.

In the first place, it must be thoroughly realised that, although cotton spinning has the one great aim of bringing an irregular mass of cotton fibres into comparative order, and making them into a strong round thread, there is such a wide variation in the condition of the raw material, and also such a great range in its ultimate product, that the industry is, as a consequence, split up into several branches; and these — principally for economic reasons, as well as structural details of machinery conducing to variation of result — might also be termed distinct processes. Four branches or departments may be enumerated, viz. waste spinning, spinning low numbers, medium numbers, and high

NOTE. — A very complete set of practical notes on these machines will be found in the author's book, *Cotton Mill Management*.

numbers. Waste spinning we are not concerned about, but the other three are part of our subject. The variation of the raw material used for either of these three purposes compels an almost corresponding variation in details of structure, in type of machine, and in the arrangement of the order or extent of the various processes. To make this clear, a list of machines in their order is given for spinning from low numbers up to high numbers, and it will be seen how the conditions vary as the better classes of cotton are used.[1]

Nos. 3 to 10

1. Double vertical opener.
2. Single scutcher.
3. Single scutcher.
4. Single scutcher.
5. Carding engine.
6. Drawing frame.
7. Slubbing frame.
8. Roving frame.
9. Mule or ring frame.

Nos. 10 to 20 : Indian Cotton

1. Double vertical opener.
2. Single scutcher.
3. Single scutcher.
4. Single scutcher.
5. Carding engine.
6. Draw-frame.
7. Slubbing frame.
8. Intermediate frame.
9. Roving frame.
10. Mule or ring frame.

Nos. 20 to 50 : American Cotton

1. Single vertical opener.
2. Single scutcher.
3. Single scutcher.
4. Single scutcher.
5. Carding engine.
6. Draw-frame.
7. Slubbing frame.
8. Intermediate frame.
9. Roving frame.
10. Mule or ring frame.

Nos. 40 to 100 : Egyptian Cotton

1. Double opener, with lap part.
2. Single scutcher.
3. Carding engine.
4. Draw-frame.
5. Slubbing frame.
6. Intermediate frame.
7. Roving frame.
8. Mule.

Nos. 80 to 100 : Egyptian (double-carded)

1. Double opener, with lap part.
2. Single scutcher.
3. Breaker card.
4. Lap machine or Derby doubler.
5. Finisher card.
6. Draw-frame.
7. Slubbing frame.
8. Intermediate frame.
9. Jack-frame.
10. Mule.

[1] Very full details of these systems are given in Vol. III.

No. 100 upwards: Sea Island Cotton

1. Single opener, with lap part.
2. Single scutcher.
3. Carding engine.
4. Drawing before combing.
5. Sliver lap machine.
6. Ribbon lap machine.
7. Comber.
8. Draw-frame.
9. Slubbing frame.
10. Intermediate frame.
11. Roving frame.
12. Jack-frame.
13. Mule.

It will be noticed in the above lists that a more delicate treatment is afforded to the better-class cottons, whilst at the same time the operation is lengthened in order to obtain a greater regularity of yarn. When we come to the highest numbers a new process is introduced called combing, closely following a preliminary course of drawing. It will be seen therefore that, throughout, the operation of drawing always follows that of the card.

The above lists show that combing is a process which is only introduced into the spinning of high numbers or counts of very good quality. As its name implies, it is primarily a combing operation—that is, every fibre of cotton is practically isolated and straightened out, in which condition it is maintained afterwards by the contiguity of the surrounding fibres. The mechanical method of performing this action introduces of necessity several of the most important effects that make combed yarns possible, and gives to them the qualities that make them so valuable for the special purposes they serve.

In the notice with which the chapter on carding was prefaced,[1] attention was called to the condition of the cotton, which rendered that process an indispensable one in the manufacture of yarns, and those remarks are doubly applicable to the subject we were now considering; but, in addition, there are several important properties that combed yarns must possess, which are practically unattainable by

[1] See Vol. I.

the use of the card alone. These properties may be summarised as follows:—First, the fibres composing the yarn must be uniform in length. From the description of the card, we are prepared to acknowledge that this result is impossible of attainment with the most perfect card of the present day, although it approaches much nearer to such a state than machines of a former period. An examination of a sliver will show beyond doubt that large quantities of irregularly stapled cotton exist, and it is to eliminate the shorter fibres that we have recourse to combing. Secondly, each fibre must be combed out as straight as possible, and must be maintained in this position. We saw that this combing action was performed very effectually by the card, but in that machine the perfect freedom of the fibres gave them full liberty to return to their naturally curly state because of the elasticity they possess. In combing, the large numbers of adjacent fibres mutually prevent this, and consequently we get the fibres laid side by side in a very level condition. Thirdly, we must have the fibres incorporated together in some kind of order. They must overlap each other in such a way as to exclude any possibility of chance in their arrangement, and so that thorough reliance can be placed upon the strength that such an arrangement gives. In the card it was seen that the fibres were massed together in a haphazard fashion, without order or regularity so far as local conditions were concerned, and we can easily see that the binding of the fibres into a strand of sliver depended on no fixed method in their distribution, and to that extent there is a palpable weakness. In the comber we have a machine that renders these objects easy of accomplishment, but the combination of mechanism that is employed in attaining this successful result has given us a machine that may be considered one of the most complicated

and ingenious of the many that are used in the cotton-spinning industry.

Before combing can be resorted to, the sliver from the card must be thoroughly prepared for what is necessarily a very delicate operation. In the first place, the arrangement of the fibres in the card sliver is (as already pointed out) of such a nature that the needles of the comber would be considerably damaged if an attempt were made to comb them in this state; and, secondly, the great irregularity of the sliver would be reproduced in the comber, and at the same time cause very unequal work to be thrown on the various organs of that machine, with a corresponding waste of good fibres. These difficulties are avoided by first passing the card slivers through a draw-frame, with the result that the fibres are partially parallelised and made more regular length for length.

In doing this, another consideration must be taken into account. When the cotton is passed through the comber, it is combed out by a series of very fine steel needles, each row having a width of from 7 to 11 in. This introduces the necessity of forming the slivers into a lap, so that a number of them lie side by side, making up the required width. The slivers are therefore taken from the draw-frame, and passed through a machine called a **sliver-lap machine.** This lap is very compactly made on a wooden core, and is about 9 to 12 in. in diameter. The cans are placed behind the machine, in number from 14 to 20, according to the size of lap desired, and the slivers guided through two or three pairs of small rollers having a slight draft. From these it passes forward between one or two pairs of calender rollers, whose object is to consolidate the lap and form a kind of fleece of the combined sliver. On emerging from these rollers it is wound on the wooden core, whose revolu-

tion is obtained by the friction produced by its resting upon large revolving bowls. The selvedge is kept perfectly free from damage by circular end-plates, which revolve with the lap, and in this way friction of the lap ends with the framing of the machine is avoided. A stop motion is an absolute necessity in a machine of this description, and in all makes of it the slivers are first passed over spoons or some other system of stopping the machine, so that directly an end breaks or a can runs empty it instantly stops.

The small draft alluded to above varies slightly, but it ought never to exceed two.

The power required for driving is usually put down as $\frac{1}{2}$ i.h.p., and its production under ordinary conditions is 450 to 500 lbs. per day.

The speed of the driving pulley on the machine varies greatly in different makers' machines, but this depends very much on the arrangement of the gearing. One large firm, who have a speciality in this machine, advocates 200 revolutions, whilst another gives a speed of 120 revolutions per minute.

The remark ought to be made here that the principle of the machine just described is also the same for the Derby doubler, with which it is often confounded.

The Derby doubler varies from the lap machine principally in the method of feeding the slivers. A long V table is used, the point being farthest away from the machine, and the cans are arranged on each side. This allows a much larger number of slivers to be used (22 to 60), and also gives a greater width of lap (10 in. to 37 in.). It was formerly extensively employed in making the laps for double carding, and is now chiefly used for the card in spinning waste and low numbers. The sliver-lap machine has, at present, almost entirely taken its place for other purposes.

In a large number of cases the lap is now taken to the comber, but before considering its treatment there, it will be interesting to notice another system which is becoming more generally adopted in the preparing of fine yarns.

The fleece taken from the sliver-lap machine, when held up to the light, is seen to consist of thick and thin places running in the direction of the length. This, of course, is caused through the slivers not being incorporated with each other, simply lying side by side, the outer fibres of each attaching themselves to those of the one next to it. This condition is unavoidable in the previous machine, and as it is not a desirable state of things, a remedy is sought in the following manner :—The slivers are taken direct from the card, and passed through the sliver-lap machine. The lap thus formed is taken to a **ribbon-lap machine and draw-frame combined.** The laps put up vary in number, but are generally six. The fleece from each is passed through four lines of rollers arranged on a similar plan to those of the draw-frame. Here they are submitted to a draft—in this case six—and they emerge attenuated to this extent. They are now carefully guided along specially curved plates, which bring them down on to a smooth table, upon which they are drawn lengthwise of the machine to its end. Each fleece in passing forward is brought under the other fleeces, as they are guided in a similar way, and by the time they reach the end of the machine they are all superimposed, and a combined lap is the result, with the irregularities reduced to an extent that shows little, if any, variation of light and shade when held up to the light. The combined lap is now passed through a series of calender rollers, which effectually consolidates them, and neutralises any tendency to licking.

A good idea of this machine, as made by Dobson and Barlow, can be obtained by an examination of the four illustrations, Figs. 28A, 28B, 28C, and 28D. It will be noted that Figs. 28A and 28B give the full gearing plan of the machine, the driving end when standing in front of the machine is shown in Fig. 28B, whilst the lap end is given in Fig. 28A. Elevations of the machine are represented in Figs. 28C and 28D. Absolute smoothness of the curved plates and table is necessary, and frequently these are nickel-plated and highly polished. The drawings are sufficiently clear and detailed as to render a further description unnecessary.

Draw and Lap Machine.

(Reference to Illustration).

A Draft wheel.
B Driving pulley.
C Front roller driving wheel, 65 to 78 teeth.
D Front roller wheel, 65 to 78 teeth.
E Front roller wheel driving F.
F Chased boss carrier.
G Back roller wheel.
H Back roller wheel driving second roller through 70s carrier.
J Second roller wheel.
K Back roller wheel driving third roller through 52s carrier.
L Third roller wheel.
M 3″ dia. calender roller driving wheel.
N 3″ dia. calender shaft wheel.
O Lap end driving bevel.
P Cross shaft bevel.
Q 6″ calender roller driving wheel.
R 6″ calender roller wheels.
S Lap drum driving wheels.
T Back lap drum wheel.
U Back lap drum wheel driving front drum wheel.
V Front lap drum wheel.
W Change wheel for draft between wood lap roller and back roller, 37 to 62 teeth.

Another example of the ribbon lap machine as made by John Hetherington and Sons is presented in Fig. 28E; it will be found a simple matter to work out the calculations from the gearing shown.

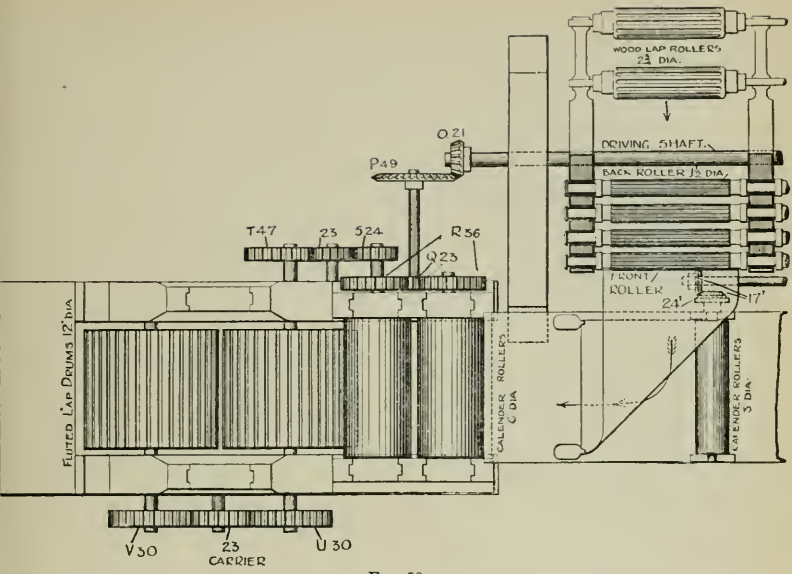


FIG. 28A.

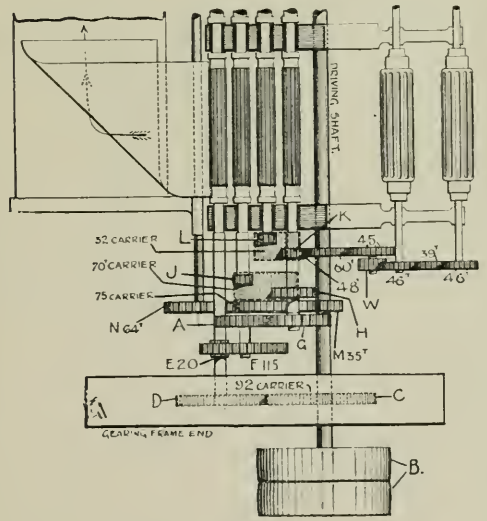


FIG. 28B.

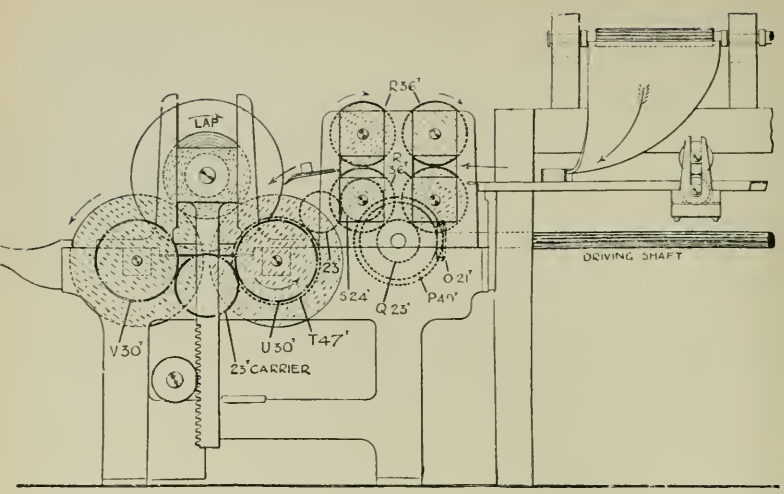


FIG. 2Sc.

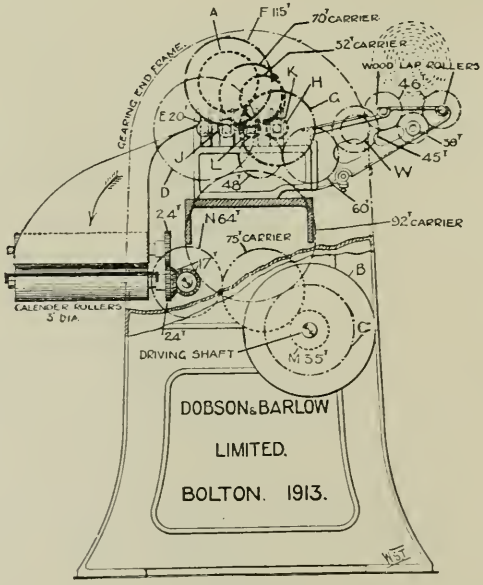


FIG. 2Sd.

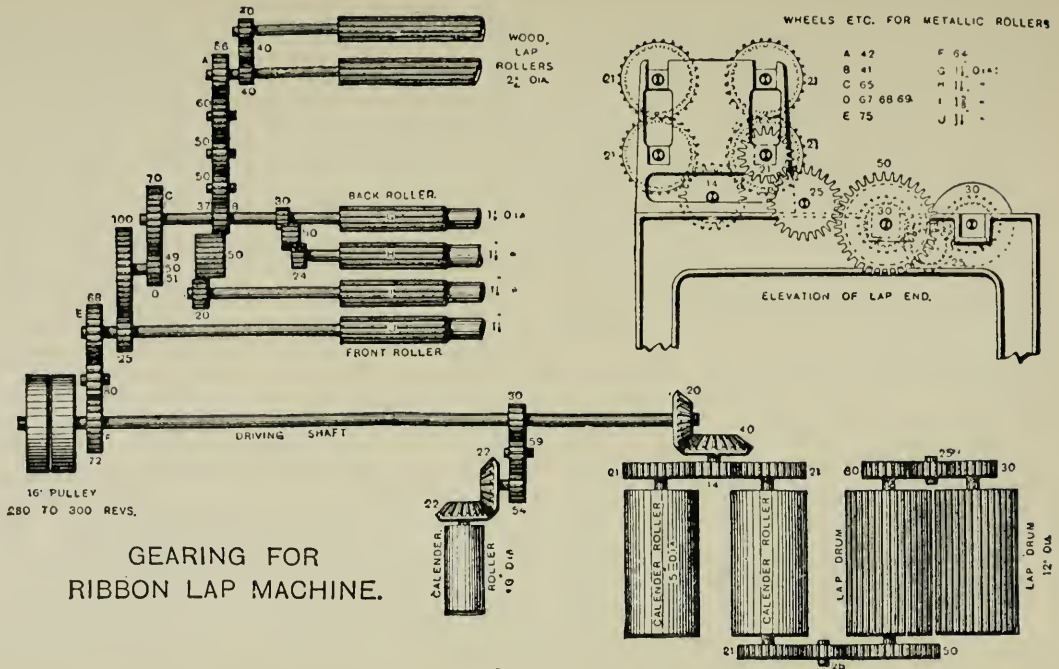

WOOD LAP ROLLERS 2½ DIA
BACK ROLLER
FRONT ROLLER
DRIVING SHAFT
16" PULLEY
280 TO 300 REVS.
GEARING FOR
RIBBON LAP MACHINE.
WHEELS ETC. FOR METALLIC ROLLERS
A 42
B 41
C 65
D 67 68 69
E 75
F 64
G 11 DIA
H 11 "
I 11 "
J 11 "
ELEVATION OF LAP END.
CALENDER ROLLER 5" DIA
CALENDER ROLLER 4" DIA
LAP DRUM
LAP DRUM 12" DIA

FIG. 28E.

Less waste is made in the comber than would otherwise be the case, and the combing process is rendered easier by the uniform thickness and equally distributed arrangement of the fibres in the lap which is fed to it.

One horse-power is required to drive the machine, and its production is equal to about 450 to 500 lbs. per day, this varying with the class of cotton used. Its driving pulley speed is usually 260 revolutions per minute.

For the very best yarn it is sometimes considered advisable to comb the cotton twice over. When this is done, the method generally adopted is as follows :—

When a ribbon-lap machine is used, the cotton is passed through the following machines in their order :—

1. Sliver-lap machine.
2. Ribbon-lap machine.
3. Comber.
4. Sliver-lap machine.
5. Ribbon-lap machine.
6. Comber.

If double combing is resorted to without the ribbon lapper, the order of the machines is as follows :—

1. Draw-frame.
2. Sliver-lap machine.
3. Comber.
4. Draw-frame.
5. Sliver-lap machine.
6. Comber.

In double combing, a system is sometimes adopted as follows :—

1. Sliver-lap machine.
2. Comber.
3. Sliver-lap machine.
4 Comber.

Description of the Comber.—We now come to deal with the combing machine itself. In the first place, a brief description as to its methods of working will be advantageous, as it will then enable a better grasp to be obtained of the various operations, when describing its mechanical movements, which effect the result.

The lap is taken from the ribbon-lap machine or the

sliver-lap machine, and placed on corrugated wooden rollers behind the comber. The machine is divided up into several sections called heads, six or eight being the usual number. Each head takes a lap, and is complete within itself, except that the driving arrangement of the complete machine is placed at one end. The lap is passed through the feed rollers intermittently, a short length at a time, this length depending upon the staple of the cotton being treated. In passing through it comes between two plates called nippers, and here it is held whilst a revolving cylinder partially covered with rows of needle combs passes through it, its needles combing out all the short and neppy fibres during the revolution. Directly this is done, a fluted portion of the cylinder comes under the combed cotton, and at the same time a movable roller is allowed to drop upon it, and as the revolution continues the combed cotton is carried away and overlapped by a backward motion of a fixed detaching roller upon the lap that has previously gone forward. Just as this is being done, another comb is brought down, and lies in the path of the cotton as it passes onwards. The finished sliver is conducted to calender rollers, which carry it forward. The various actions are repeated at a rapid rate, and a continuous fleece of combed cotton is delivered into coiler cans at the end of the machine.

In order that the above-mentioned actions may be better understood and illustrated, a section through the principal features of a machine is shown in Fig. 29. Although the drawing represents a double form of comber, it will be seen, as the description is given, that it differs very slightly from the single machine, the difference being in the cylinder, which contains only one set of combs and one flutted portion. (Compare Fig. 31.)

The lap is placed in position upon the wooden rollers, whose revolution unfolds it and feeds the sheet of cotton down a highly polished plate in the direction of the arrow.

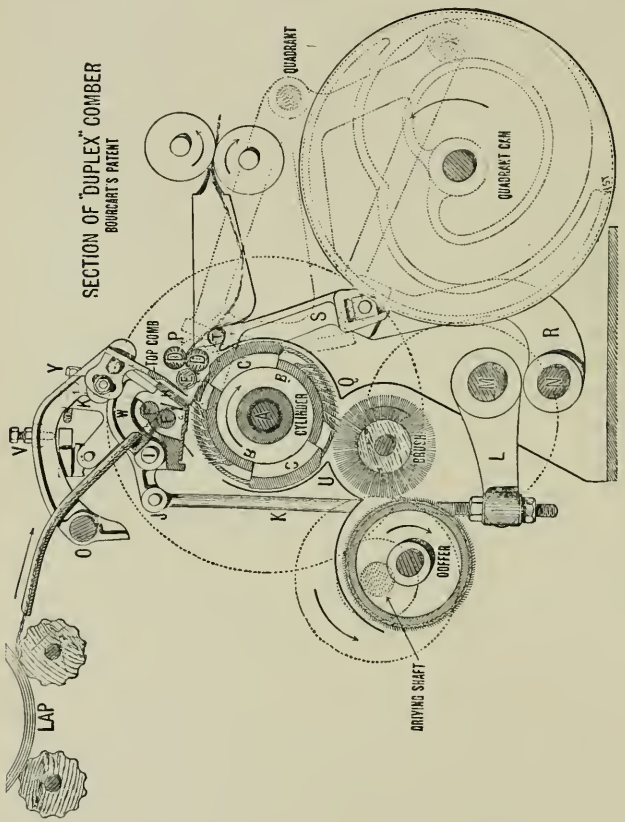


FIG. 29.

The feed rollers F F carry it forward intermittently, the exact amount of the feed being regulated according to the staple of the cotton. The length fed goes forward between the nipper H and a cushion plate G. When sufficient has

passed through the cushion plate, H descends and presses against the cushion G, thus holding the cotton very firmly. At the same time the needles B of the revolving cylinder come round into contact with the portion of the lap projecting from the nipper, and, in passing through it, thoroughly free it from its short fibres and impurities left in by the previous processes. Immediately the combs have finished their work, the rollers D D are actuated so as to turn back a short portion of the cotton that they took forward at the preceding operation, and just as this is done the fluted portion C of the revolving cylinder has moved so that the leather detaching roller E can be brought into contact with it. This leather-covered roller, driven through friction by the fluted detaching roller D, with which it is pressed into contact by springs or weights, directly it touches the fluted segment C, takes the combed cotton forward. Simultaneously with this motion, the top comb comes down right in the path of the cotton, and so the fleece, in passing through it, is cleared of any short fibres that may have been held by the nipper. It will be seen that this action completely separates the combed portion of the cotton from the rest, and consequently a piecing must be effected. This is done by causing the fluted detaching roller D to return a portion of the combed cotton it has taken forward, and, whilst the cotton is being drawn through the top comb, the roller E overlaps a portion of its delivered cotton upon that part that has been returned by roller D, and in this way a piecing is brought about.

The forward and backward motions are obtained in the following manner:—A pinion P rides loose upon the end portion of the detaching roller D. The motion that P receives is transmitted to D through a clutch wheel, which is actuated by means of a cam. Gearing into P is the

quadrant shown in dotted lines, one end of which carries a bowl X, which receives its motion from the quadrant cam. This cam is formed so that it will cause the detaching roller D to turn backwards a given length and immediately turn forward a greater distance, a portion of which is used for piecing purposes.

When this is done, the rollers D and E are at rest whilst the combing process is going on, and so the quadrant cam has a portion of its revolution idle so far as the quadrant is concerned, the clutch wheel at the same time being out of gear. When the combing process is finished, the clutch is put into gear, and the cam, acting on the quadrant, repeats the operations of backward and forward motions. The leather detaching roller E is put into and taken out of contact with the fluted segment C by means of the lever S centred at T. This is actuated through the lever R by the roller cam.

The top comb is centred at O, and its setting is effected through the set screw at V.

The nipper H, centred at I, receives its motion through the lever L, and the rod K from the nipper cam, its movement being regulated by the cam on the one hand and by the setting screw Y on the other. The centre I is carried by a kind of cradle, upon which the cushion plate G is fixed. The cradle, being centred at W, allows the cushion plate to yield a little, and so be depressed quite close to the cylinder, when the nipper H presses against it. This enables the needles to effect a better combing, since the cotton is brought as near to them as possible.

The foregoing is only a brief description of the comber's action. An examination of its details and full explanations of its operations will follow.

When considering in detail the various movements of

the comber and their results, the broad fact must be kept in mind that the machine depends entirely upon an intermittent action of the several parts, and each operation is so dependent upon the other that the slightest variation from the correct time of acting destroys the efficacy of the machine, or neutralises to a considerable extent the objects for which it is used. These several operations may be summarised as follows:—The feed motion, in which the lap is fed to the cylinder to be combed; this is of necessity intermittent; the length that is fed is also dependent upon the staple being used. The nipper motion, for holding the cotton during the process of combing; it is intermittent in its action, and is arranged to allow the cotton to go forward after it has been acted upon by the cylinder. The actual combing operation follows next, by means of the rows of needles on the cylinder passing through the lap, after which the combed portion is taken on by the detaching roller. The backward and forward motion of the detaching roller; and, finally, the delivery of the finished material by calender rollers to the draw box and coiler. In addition to the above, there are several movements taking place either intermittently or continuously during the cycle of operations enumerated, but their dependence is so close on those given that it is not advisable to speak of them as distinct actions. Attention will first be given to the feed motion, and whilst the descriptions will be illustrated as fully as possible as the various details are dealt with, it is recommended that reference should be made to as many of the drawings as possible, in order to gain a clear idea of their relative positions and importance.

A drawing is given in Fig. 30 showing the method generally adopted for obtaining the intermittent action of

the feed rollers. A is the cylinder shaft, driven from the driving shaft by gearing through the large wheel B (see Fig. 29). On this wheel a disc plate C is fastened containing a pin D. A little distance from the axis of the cylinder is a stud carrying a star wheel E, into the teeth of which the pin D gears during a portion of a revolution

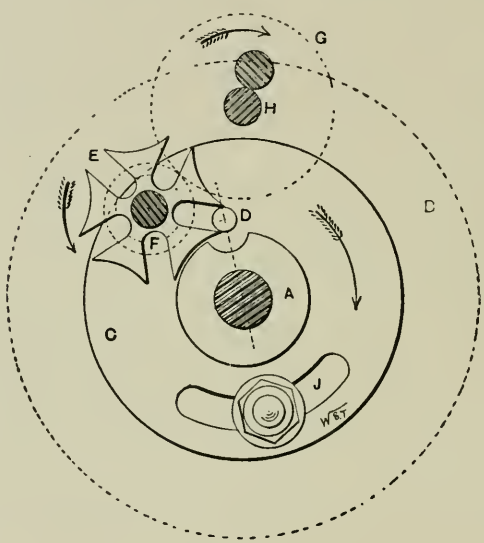


FIG. 30.

of the cylinder. The stud also carries a wheel F, whose pitch line is shown, and which works into a wheel G on the feed roller H. This arrangement contains all the requisites for the desired action, and the following description may be given as to its precise working. The cylinder is built up alternately of needles and a fluted surface—the needles for combing and the fluted surface for carrying the combed cotton away. Clearly the feed cotton must be

delivered to the cylinder just before the fluted segment comes forward; this permits the delivered cotton to be drawn forward when the leather detaching roller comes on the fluted segment. This introduces the necessity of some setting arrangement that will enable this delicate adjustment to be made; and so we find, as in the sketch (Fig. 30), that the pin D is attached to a movable disc C, which in its turn is connected to the wheel B by the screw J. In this way the engagement of the pin D with the star wheel E can be very carefully and exactly made so as to fall in with the correct portion of the cylinder's revolution. The star wheel itself is made with five teeth, as shown. The pin D can only act on it during part of a revolution The remainder of the time it is stopped and made immovable through the concave formation of its outer circumference being in contact with a circular portion of the boss on C. The connection of E with the feed roller by gearing is a necessity, because the machine must be capable of working various staples of cotton, and consequently there must be some facility for obtaining a variation of the length delivered by the feed roller H. This is readily obtained by the interchangeability of the wheel F with larger or smaller ones just as they are required. In this way the revolution of H can be regulated as to the amount it delivers to the cylinder.

The above arrangement is the one generally adopted for a single nip comber, but when a "duplex" or double action comber is made, it is clear the feed roller must deliver the required length of cotton twice during one revolution of the cylinder, because in such a case the cylinder has a double set of combs and two fluted segments, and for each set the feed rollers must deliver material. The necessary effect is obtained by using two of the pins

D in the disc C, one being placed diametrically opposite the other. In this way the star wheel is acted upon twice during a single revolution of the cylinder.

It will be understood that the intermittent action of the feed rollers must result in the same motion being given to the fluted wooden rollers upon which the lap rests when placed behind the machine. The requisite motion for doing this is transmitted by means of suitable gearing, which will be illustrated at a subsequent part of the description.

The next feature to demand attention is that part of the comber known as the "nipper." We have already seen that this is a combination of levers which are brought into play for the purpose of holding the cotton firmly, without injuring it, whilst the cylinder combs out the portion of the lap that protrudes. In explanation of this action a drawing is given in Fig. 31, to which reference will be made in the following description. The principal features shown are similar to those in Fig. 29, but in the present case a single combing cylinder is exhibited; to this the remarks will apply. A is the cylinder, whose fluted portion C has just made the piecing and carried forward the combed portion of the sliver. Directly this has happened, the feed rollers F F must deliver a sufficient length of the lap for the next combing operation, and at the same time the cushion plate G and the nipper knife H must open to allow this length to go forward. Immediately this is done, the nipper and cushion plate are brought together, and hold the cotton as the teeth of the cylinder pass through it. The details of this action will now be explained.

The method adopted for obtaining the opening and closing effect of the nipper is generally by means of a cam,

as shown at R; this cam is grooved in such a manner that, acting through a series of levers, it produces the necessary movements of the nipper. A shaft M goes the full length of the machine, and on it are placed a series of levers L, one being used for each head. These levers have connected to them short connecting rods K, the upper part of which is connected by the pin J to one end of the nipper arm, whose fulcrum is at I. On the shaft M a lever N is fixed, which carries a bowl P, working in the groove on the face of the nipper cam. When the bowl receives movement from the cam it gives a rocking motion to the shaft M, and this is transmitted by the levers L and connecting rods K to each nipper in the machine simultaneously: the cam is formed so that whilst revolving it keeps the nippers opened a sufficient length of time to allow the fed cotton to go forward. This action is shown taking place in the sketch, but as the cam continues its revolution, P will be moved a farther distance from the centre to P_1 until the point Q is under the shaft. When this occurs, it will be seen, the nipper is closed, and in this position it will remain as long as the bowl is working in the concentric part of the groove of the cam QRQ.

In connection with this intermittent action of the nipper, one or two considerations have compelled an arrangement of the levers to be made which is not so simple as the description just given would imply; therefore it will be well for the reader to closely follow the description. The cam, as already described, causes the nipper arm to turn round I as the fulcrum, but this is only a part of its action; for directly the nipper H touches the cushion plate G (the cotton, of course, between them) the plate is forced downwards. Now it will be noticed that G is carried by a frame or cradle which also carries the fulcrum I; this frame is

centred at W, and kept in position by a strong spring attached to a projection S and the framing of the machine. When, therefore, G is depressed by the pressure of H it

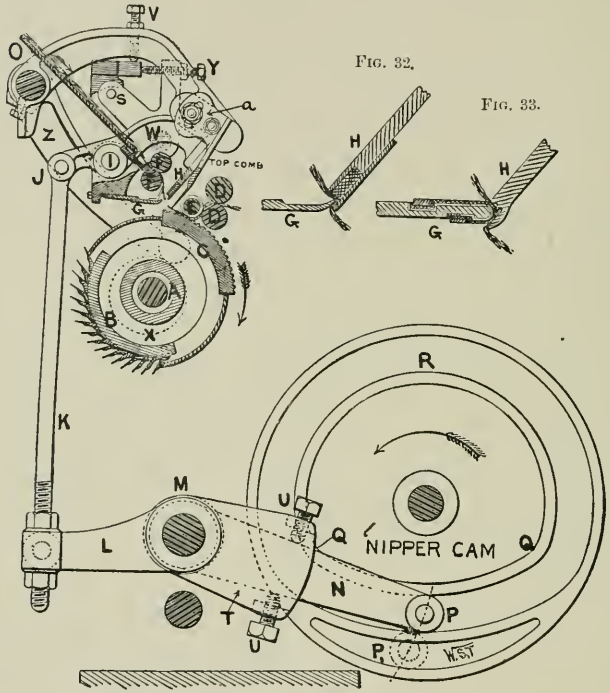


FIG. 32.

FIG. 33.

FIG. 31.

commences to move in a smaller arc of a circle, having W as its centre. This movement, it will be seen, brings G very close to the surface of the cylinder, and consequently enables the cotton to be combed very close to the nip. When the combing is finished the nipper begins to return to its original position; but it must clearly be seen and

understood that the cotton is not free from H and G until G occupies such a position that when the cotton is at liberty to be taken forward it is compelled to pass through the teeth of the top comb. This position is a very delicate one to adjust, and is regulated by means of the setting screw Y, which bears against a portion of the framing (shown by shaded lines in the drawing).

If some arrangement of this kind was not made, the cotton, after being combed, would lie in the teeth of the cylinder or on the surface of the fluted segment. In this position it would be impossible to pass it through the top comb, and as a consequence the combing operation would give only a portion of the good results that are now obtained from it. By allowing the cushion plate, whilst still holding the cotton, to be raised away from the cylinder, we raise the combed fibres into a position where they are obliged to pass through the top comb as they are taken forward by the roller E.

It was formerly the custom to place the nipper cam at one end of the machine, but the absolute exactness that was required by the simultaneous movement of each nipper was found to be slightly interfered with by the torsion that was produced in the shaft M. Strengthening the shaft was the first remedy tried, but ultimately the best arrangement was adopted of placing the cam in the middle of the comber, in which position it will be found in all the latest and best machines.

We have already spoken of the great degree of accuracy that must be maintained between each action. Every means is adopted to obtain this precision. It will readily be understood that the closing of the nippers and their opening at the right moment is a very important matter, so we find that adjusting arrangements are provided to

obtain the necessary regulation, as shown at U U and at the lower part of K, where it is connected by a swivel joint to the lever L. From these points the exact movement of H can be regulated. N in reality is a lever working loose on the shaft M, but is so arranged that by pressing against the screws U it moves the lever T, which is keyed on the shaft. This enables an adjustment to be made of a very delicate character when the cam is being set.

An enlarged view of two kinds of nippers is shown by Figs. 32 and 33. In Fig. 32, as made by Dobson and Barlow, the cushion plate G is made with a dull, thin edge, and this is pressed against a strip of leather inserted in the nipper H. A firm hold of the full width of the lap is obtained by this means, and whenever the leather requires renewing it is a simple matter to turn it round or replace it. The other illustration (Fig. 33) shows a well-known method of getting the same results, but it is not of so simple a character as the previous one, and the replacing of the leather is more difficult, and requires greater care.

The movement of the top comb is obtained in the following manner:—On cylinder shaft is fixed a cam X, shown in dotted lines, which, during a revolution, actuates a lever Z which rests upon it. This lever is fastened to the shaft O, to which is also fastened the top comb, so that the cam X, through the lever and the shaft, raises and lowers the comb as required. The comb's adjustment is obtained by means of the setting screw V, which rests upon a fixed portion of the machine. Several other adjustments can usually be made—for instance, the position of the top comb can be altered by the set screws at "a," a radial slot being provided to allow of this, and also the cushion plate G can receive a slight regulating through the set screw shown in the sketch. As a rule, small projections are fastened on

the cushion plate in order to direct the lap on to the cylinder, as well as to prevent bad selvedges forming.

The next motion that requires consideration is that known as the "roller motion," or, more correctly speaking, the detaching roller motion. A general idea of its action has already been given, but a reiteration of its main features will enable its functions to be better apprehended in the following explanation. After the combs of the cylinder have passed through it, the cotton is raised up out of contact with the teeth by the action of the cushion plate. Directly this happens, the combed portion must be pieced up to the cotton that was acted upon during the previous combing action, and which has been carried forward by the rollers D. To do this a part of the finished sliver must be returned so that the new portion will overlap it, after which the combined length will pass on to the coiler. To obtain this backward motion, and then a forward motion, to immediately follow it, has been the occasion for the display of much ingenuity. Two of the principal means employed for effecting it will be given at this stage. The first is called the quadrant motion, and is illustrated in Fig. 34. Reference will also be made to Fig. 29, which represents this motion in another position, and is suitably depicted to serve as an illustration to this part of the subject.

On the shaft F is fixed a cam called the "quadrant cam." Working in the groove on the face of this cam is a bowl X, carried by one end of a specially formed lever, whose centre is at B, and whose other end is formed as part of a wheel with teeth. From this feature it receives its name of quadrant. This toothed portion gears into a small wheel P, which rides loose upon the detaching roller D, but which, when occasion demands it, can be put into gear with a clutch wheel fastened on the detaching roller, and in this

way it gives motion to D. In the drawing (Fig. 34) the position of the cam is such that the wheel P is on the point of being reversed, or, in other words, receiving its backward motion. The amount turned back varies of course according

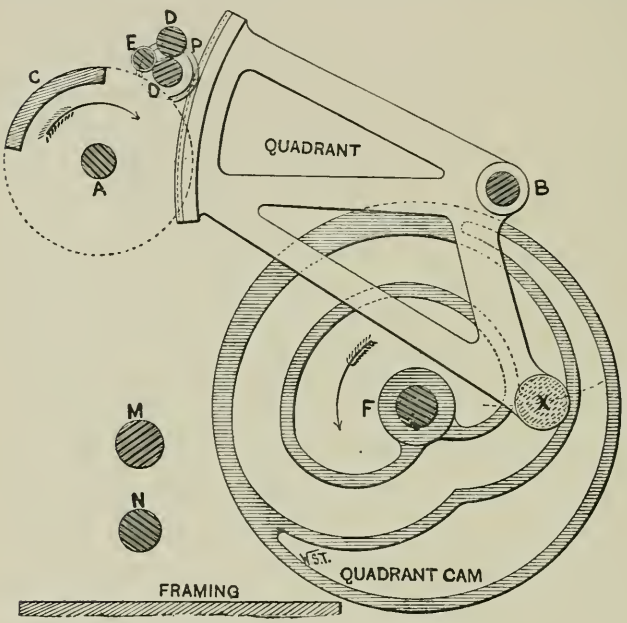


FIG. 34.

to the staple of the cotton being worked, but from $\frac{3}{8}$ in. to $\frac{5}{8}$ in. is usual. When the bowl X has approached the centre as near as the groove will allow, it immediately begins to move outwards again, and it will be noticed that this outward movement will result in the roller D taking the cotton forward, and as the groove of the cam extends further from the centre of the shaft than the point where

the backward motion begins, we can readily see that a longer length will be delivered forward than the amount returned. The difference between the two lengths will, of course, give us the total length of finished sliver the machine delivers per "nip," as it is termed.

A clearer understanding of this complicated action may be obtained by referring to Figs. 35 and 36. Here we have the cam detached from the rest of the machine, and a plan of the mechanism is also given, so that the two actions can be easily followed.

The black spots in the centre of the groove represent the position the centre of the bowl occupies as the cam revolves.

When the bowl is on the line A the backward motion is on the point of beginning, as we saw in Fig. 34. At the same time the wheel P (Fig. 36) must be put into gear with the clutch F, which is keyed on the detaching roller D, otherwise the roller will remain stationary. So at point B (Fig. 35) the clutch H must be set so that the clutch wheel P is put into gear. As the cam revolves, the line C will represent the lowest position the bowl X can attain, and thus the backward motion is finished, and is immediately followed by the forward motion. Usually, however, a very slight interval is allowed between the finish of the backward motion and the beginning of the forward part, so as to allow the leather detaching roller to be brought down on to the fluted portion of the cylinder, which has by this time been brought round, and occupies the position suitable for it. This interval is shown from C to D. Afterwards, onwards to F, the forward motion continues. When this point is reached, as is shown in Fig. 29, the bowl is working on a concentric part of the cam groove, and of course no further motion of the detaching roller can take place, and

in addition the clutch is brought out of gear at the same time. It takes a slight interval to do this, and the drawing represents it from G to H. Just before the forward motion is completed, it is necessary to move the leather detaching roller E (Fig. 34) from the flutes of the cylinder, so as to be clear of the teeth as they come forward. The point E represents that part of the cam occupied by the bowl when

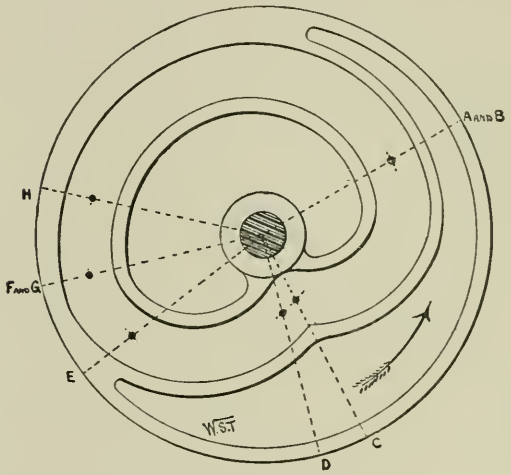


FIG. 35.

this is done. From H round to A again the cam is inoperative so far as moving the roller D is concerned, because the clutch is out of gear, and the movement of the quadrant is simply one of preparation for the next backward motion. The above description can be summarised, so far as regards the action of various parts of the cam, by the following table :—

References to Fig. 35

A Beginning of the backward motion.
B Beginning of the clutch going into gear.
C Finish of the backward motion, and beginning of the forward motion.
D The leather detaching roller touches the fluted segment of the cylinder.
E The leather detaching roller leaves the fluted segment of the cylinder.
F Finish of the forward motion.
G Beginning of the clutch coming out of gear.
H Finish of the clutch coming out of gear.

The above cycle of actions are practically the same

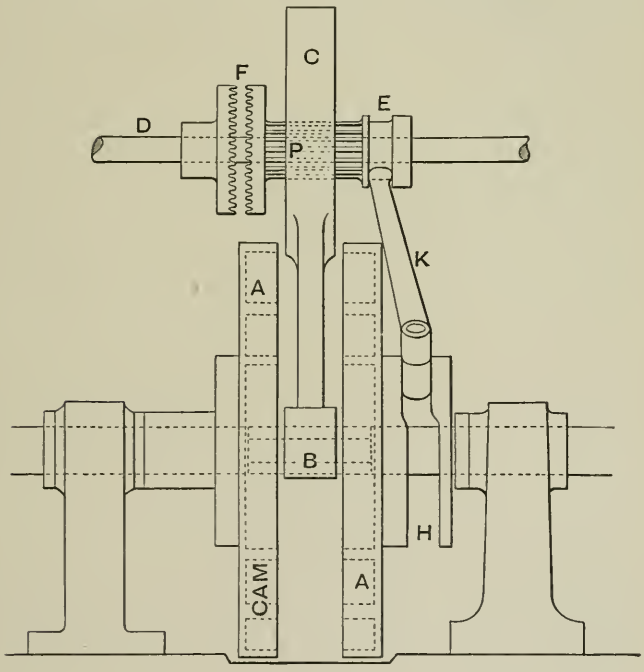


Fig. 36.

in a double form of comber, the only difference being that the cam revolves twice during one revolution of

the cylinder, and also that the curves and intervals are slightly different, owing to the flutes and combs not being proportioned on quite the same lines as in the single form.

Another method of actuating the detaching roller is by means of the notch wheel arrangement. This is the most general system of accomplishing the above purpose, and a drawing is given in Fig. 37 of its essential features, so that its action can be clearly understood. A is the cam shaft, on which is fastened the face cam B; working in the cam groove of B is a bowl C, carried by one end of a lever centred at D, and which is shown in the drawing in dotted section lines; the other end of the lever carries a catch E, a projection on whose end fits in the notches cut on the periphery of a circular plate F, which also has D as its centre. It will be noticed that the projection on the catch E is square, and that the notches are also of the same shape, so that whichever way the catch moves the plate must follow. The catch is kept in position by the spring G. An examination of the drawing will show that the movement of the cam B will cause a backward and forward motion to be given to the bowl C, exactly in the same manner as explained in the previous method. The position occupied by the bowl in the sketch shows it to be on the point of commencing the backward movement. This effect is transmitted by the catch E to the notched plate F. On the same centre D as the plate is an internal wheel H, into which gears a small pinion J fastened on the detaching roller, so that any motion given to the notched plate will be given in a less degree to the detaching roller, according to the relative number of teeth in each wheel. Now, since the detaching roller is stationary except during the backward and forward motions, some means must be provided

of taking the catch out of gear with the notch wheel. This is provided for in the drawing by connecting to the catch a short lever carrying a bowl K, which rests upon the outer

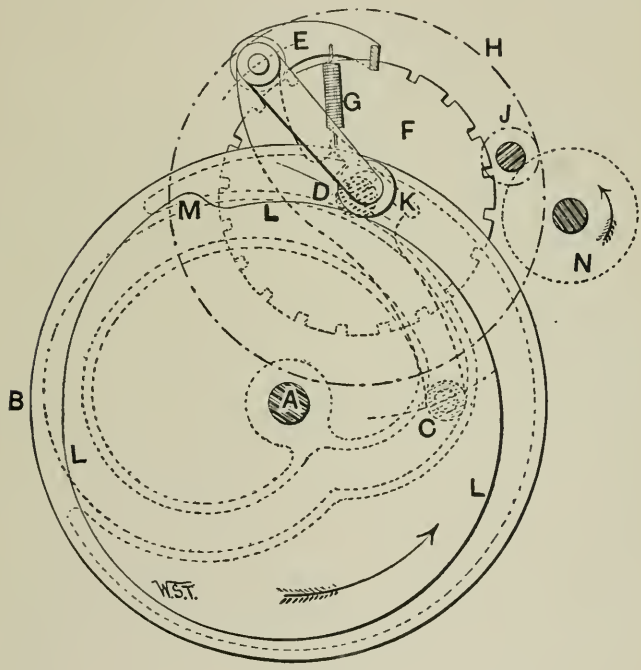


Fig. 37.

circumference of a cam plate L, fixed on the shaft A. So long as it is necessary for the catch E to engage with the notched wheel F, the form of the cam plate L is such as to have no effect on it, but when the forward motion is finished the catch must be taken out of gear, and so L is made with a curved projection M, which during its revolution comes under the bowl K and lifts the catch E out of the notch. The

necessary position of the projection M, so that the timing of the various actions is correct, can be readily made.

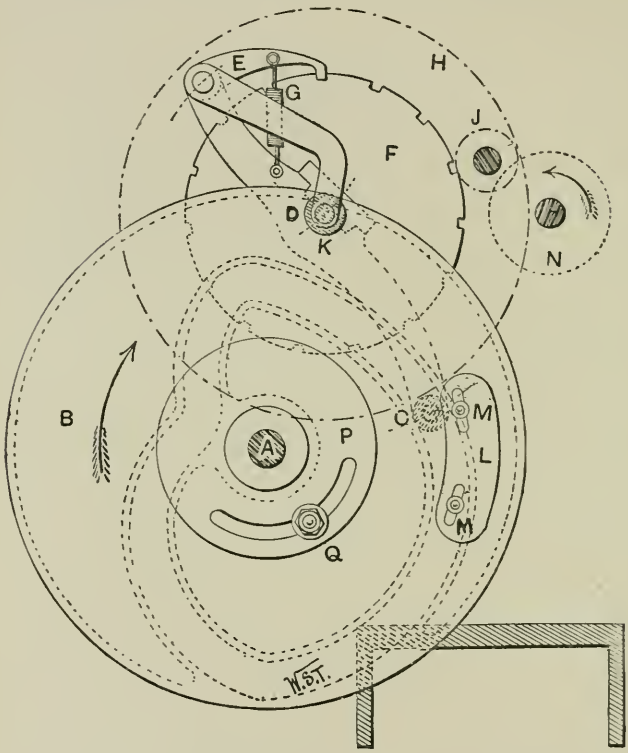


Fig. 38.

The cylinder is shown in dotted lines at N, and also the direction of its rotation.

In Fig. 38 we have an almost identical arrangement with the last one. A close inspection of the illustration will, however, disclose one or two details that are worth

observing. In the first place, the cams are a little different at the points where the changes are made. This is a detail which does not affect the actual work the cam has to perform, but from a practical point of view it is advisable to avoid an extreme or sudden change in the cam's action, so that slightly more rounded corners are the best. In the next place, there is a different method of lifting the catch E out of gear with the notched plate F. In this case the cam plate is dispensed with, and in its place a movable plate L is fastened to the back of the grooved cam B. Its position can be easily altered to suit the requirement by means of the screws M, this plate during the revolution of the cam B being brought under the bowl K (which in the drawing happens to occupy the same position as the centre D of the notched wheel), and raises it so that the catch E is lifted out of gear with F. The cam B itself can be adjusted to the necessary conditions of timing, etc., by its connection with the plate P and bolt Q.

The cylinder N is shown in its relative position to the other portions of the drawing.

We now come to the consideration of the means employed to raise the leather detaching roller E out of and into contact with the fluted segment of the combing cylinder. It will be understood from previous descriptions that the leather-covered roller is always in contact with the bottom fluted detaching roller D, and is kept so by means of weights or springs. During the backward motion its revolution is given to it purely by the friction of itself with D, but directly the forward motion commences, it falls into contact with the fluted segment of the cylinder, and this motion helps to cause E to rotate. Now, unless the surface speed of D is timed exactly like the surface speed of the cylinder, we can readily see that the roller E

between the two surfaces will suffer considerable damage to its leather covering, as well as producing inferior results. To prevent this occurring, the cam grooves which actuate the quadrant or the notch wheel are very carefully designed, and in some cases every cam is milled out so as to ensure a perfect action.

In Fig. 39 an illustration is given which will show very clearly the method of actuating

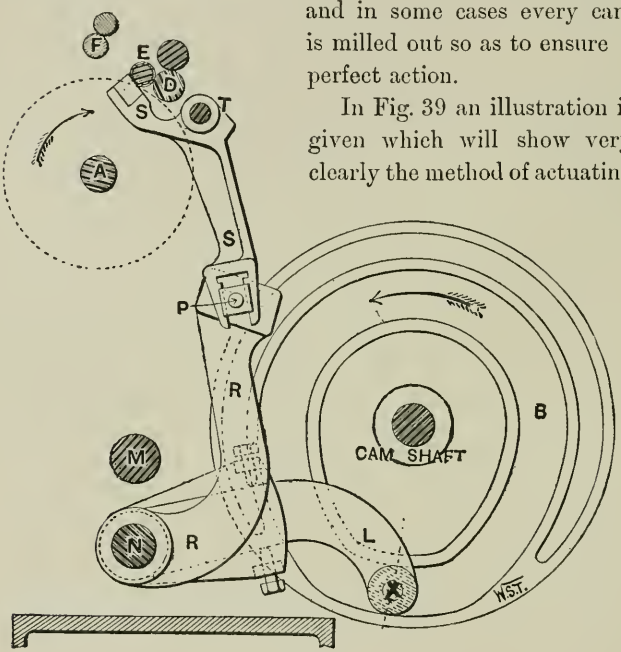


FIG. 39.

the leather detaching roller. A cam B fixed on the cam shaft has working in its groove a bowl X, which is carried by a lever L centred on the shaft N. The shape of the cam groove is such as to cause X to approach and recede from the cam shaft centre, and through this motion the shaft N receives a rocking action. On the same shaft N is fixed a series of levers R, which carry a stud P. This stud works in a slide

formed in one end of the lever S, which has T as its fulcrum, and whose other end provides the surface upon which the ends of the leather detaching roller rest. We can now see, by following the movement of X as it is changed by the

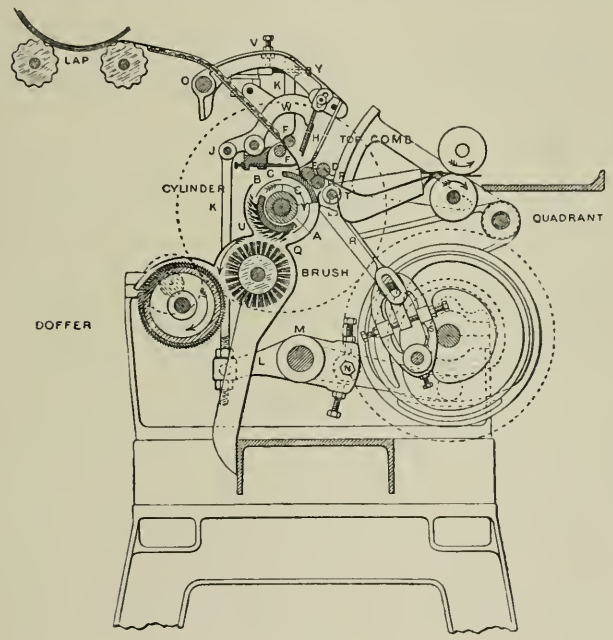


Fig. 40.

special form of the cam B, that its motion will affect, through the levers R and S, the position of the roller E. In the position shown in the drawing (Fig. 39), E is working in contact with the cylinder, and so assisting in the forward motion, but the further revolution of B will lift it out of this position, and keep it so until the flutes of the cylinder again return to the necessary place for the

repeated action. Adjustments can be made for the extreme exactness that is required, by the setting arrangement on the lever L, and also by the regulating of the stud P.

Fig. 40 shows Dobson and Barlow's improvement on

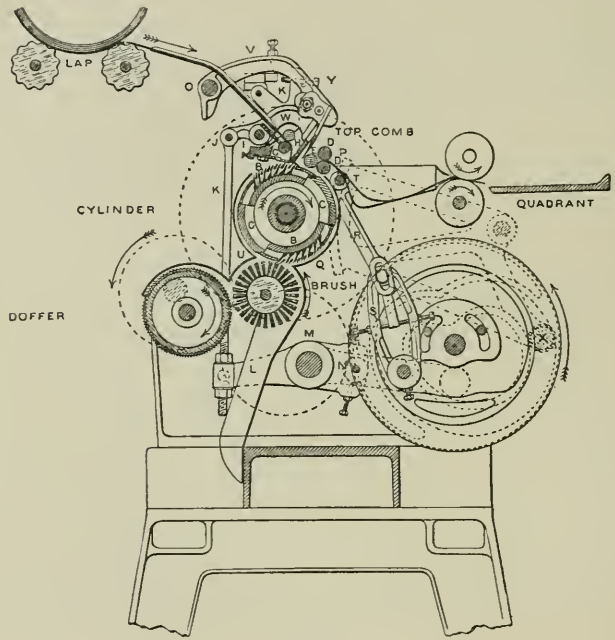


FIG. 41.

their old method as depicted in Fig. 39. The levers have been rearranged and reduced in number, there are therefore less moving parts, and an action free from vibration and of a more capable and delicate adjustment is obtained. Fig. 41 illustrates its application to the double form of comber, and this drawing may be found useful in connection with the description on page 58.

A review may now be made of the previous descriptions of the various actions produced by the mechanisms just described, as far as they all affect that portion of the machine just above the cylinder. A series of drawings has been prepared illustrating that region of the machine, and from them the following explanations will be summarised.

In Fig. 42 the feed rollers F have delivered a suitable length of staple, the nippers G H have closed up and hold it fast, and the cylinder teeth are upon the point of commencing to comb it. It will be noticed that the first rows of teeth are of a coarser pitch than the others that follow. The teeth themselves are also longer, stronger, and farther apart. Each row gradually becomes finer in this respect until the last row, which is composed of a large number of very fine needles close together. The object of this arrangement is to act progressively on the cotton. The coarser needles prepare it for the finer ones which follow, and so the fibres are treated in a way that ensures the minimum of damage with the maximum of cleaning. The top comb is out of the way, and the sliver previously taken through is shown to be in a position ready for the backward motion.

Fig. 43 is practically the same drawing, but showing the conclusion of the combing action. It will be seen that the cotton already taken forward is quite separated from that just combed, so it is necessary to piece it up, and this is performed by an overlapping process.

In Fig. 44 this process is shown. The roller D has been turned in a backward direction, and presents a length of cotton ready for piecing. The roller E has been placed on the fluted segment, and naturally grips the end of the combed cotton, which, during its revolution, it carries forward and overlaps on the returned portion, so that an

effective joining is the result. Just before this action however, the nipper is opened and the top comb T comes down into the path of the lap, so that as E carries the

Fig. 42.

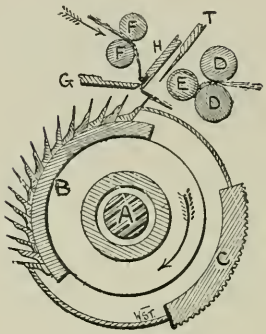
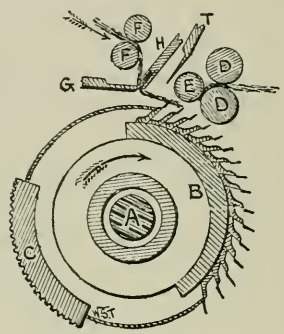


Fig. 43.



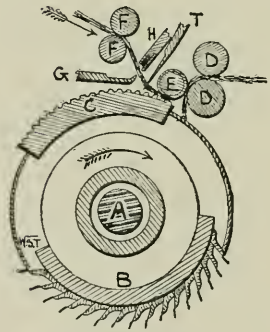


Fig. 44.

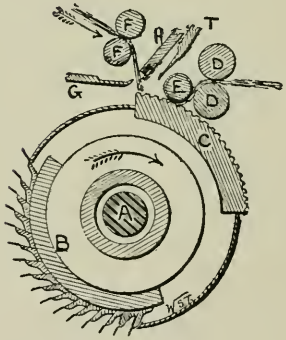


Fig. 45.

cotton forward it is drawn through the needles of T and receives a good combing. Fig. 45 illustrates the finishing cycle of movements, and shows E to be on the point of being raised out of contact with the cylinder; the rollers

are delivering cotton for the approaching combs, and directly this is done the nipper will close.

It may be as well at this point to note that the amount of cotton taken forward by the detaching roller is not equal to the amount combed; only the longest fibres are taken forward, so that the remaining fibres, augmented by the fresh fibres fed by the feed rollers, are again combed, and probably the majority of fibres, before being absolutely free to pass forward, are combed several times.

In regard to the cylinder itself, it is now generally made so that the greatest facility is afforded for taking it to pieces and replacing very quickly damaged portions. As a rule, it is built up in segments around the centre, and is composed almost entirely of turned work, in which form duplication becomes an easy matter. Each row of needles can be removed for repairs without interfering with the rest, so that the former arrangement, which caused great difficulty in this respect, is completely altered and improved.

It used to be the common practice to make combers to take only laps up to $7\frac{1}{2}$ in. wide, but at the present time improvements have been made in the way of guides on the cushion plate, which prevent bad selvedges through spreading, and enable a wider lap to be used without increasing the length of the machine. But machines are not now confined to narrow laps. Up to $10\frac{1}{2}$ in. laps are frequently made both for the single and double form of the comber. Six to eight heads are the usual number forming one machine.

So much improvement has taken place in the comber during the last few years that its production has been greatly increased, and the number of nips per minute, which used to be about 60, has gone up by degrees until now

many machines at work giving good results are running at 96 and even 100 nips per minute.

The comber takes to drive it about $\frac{5}{8}$ i.h.p. to $\frac{7}{8}$ i.h.p. according to the following table :—

Ordinary . . .	6 heads,	$\frac{5}{8}$ i.h.p.	8 heads,	$\frac{3}{4}$ i.h.p.
"Duplex" . .	6 ,,	$\frac{3}{4}$,,	8 ,,	$\frac{7}{8}$,,

The pulley varies in size and speed according to the make of machine, one maker using a 12-in. pulley at 230 revolutions, whilst another, with a 10-in. pulley, runs at 325 revolutions.

The following tables will be useful as conveying much valuable information on the comber, and presenting several points of interest to the student :—

ORDINARY COMBER.

No. of nips per min.	Weight of lap per yd.	Width of lap.	Waste per cent.	Lbs. per head of combed sliver.	Kind of Cotton.
	dwts.	in.			
80	8	$7\frac{1}{2}$	20	6·37	Sea Islands.
80	9	$8\frac{1}{2}$	20	7·22	,, ,,
80	11	$10\frac{1}{2}$	20	8·92	,, ,,
80	9	$7\frac{1}{2}$	18	7·5	Egyptian or American.
80	$10\frac{1}{2}$	$8\frac{1}{2}$	18	9·0	,, ,,
80	13	$10\frac{1}{2}$	18	11·15	,, ,,

The above productions are based, as will be seen, on a speed of 80 nips per minute; but if, as is now the case, machines run up to 100 nips, the production, of course, will be correspondingly increased.

"DUPLEX" OR DOUBLE COMBER.

No. of nips per min.	Weight of lap per yd.	Width of lap.	Waste per cent.	Lbs. per head of combed sliver.	Kind of Cotton.
	dwts.	ins.			
120	8	$7\frac{1}{2}$	20	9·23	Sea Islands.
120	9	$8\frac{1}{2}$	20	10·47	,, ,,
120	11	$10\frac{1}{2}$	20	12·93	,, ,,
120	9	$7\frac{1}{2}$	18	10·88	Egyptian or American.
120	$10\frac{1}{2}$	$8\frac{1}{2}$	18	13·04	,, ,,
120	13	$10\frac{1}{2}$	18	16·12	,, ,,

Heavier productions than these can be obtained if more medium qualities are desired, but for the best work the above results represent a good average.

The necessity for great care and experience in the management of the comber will be apparent to all who have followed carefully the description of this complicated machine. The setting of the various actions demands extreme exactness and a knowledge of the material being worked, or else considerable waste and probable damage to some part of the machine will result from such negligence. Waste may be increased more than is desirable by several causes—for instance, if the nippers do not close at the right moment, that is, before the needles reach the cotton. This is generally spoken of as the nipper closing too late. Feeding too late produces excessive waste, and the angular position of the combs on the cylinder gives a similar result. The setting of the top comb in relation to the cylinder and nipper, unless carefully performed, yields more waste than is necessary, and consequently too close setting is to be avoided. The method of setting and the gauges used for

the operation vary of course with different makes of machines, so that little purpose would be served in giving the *modus operandi*. It will be sufficient to intimate that the following points are important items in the process :— The distance between the flute of the detaching roller and the front edge of the fluted segment of the cylinder; the distance between the detaching roller and the cylinder; the distance between the edge of cushion plate and the fluted detaching roller; the position of the cushion plate relative to the needles on the cylinder when the nipper is closed; the distance apart of the feed roller and the fluted detaching rollers. In addition to these, facilities are provided to enable each action to follow in its proper order. An index wheel is marked with numbers suitable for various settings, and by turning these numbers to the fixed pointer, the cams, cylinders, etc., can be fixed on their shafts, and adjusted correctly for any given set of conditions. In order to convey an idea of the numbers used, the following table is given, and represents the practice and arrangement of a well-known firm of machine-makers, whose work on this machine amounts almost to a specialty :—

	Egyptian.	American.
Feed rollers move at . . .	$4\frac{1}{2}$ to 5*	$6\frac{1}{4}$* to $4\frac{1}{4}$
Detaching roller moves forward at .	6* ,, $6\frac{1}{8}$	$6\frac{7}{8}$,, $5\frac{3}{4}$
Detaching leather roller touches segment at	6 ,, $7\frac{1}{4}$	$6\frac{3}{4}$,, $6\frac{1}{2}$
Top comb comes down at . .	$5\frac{1}{2}$,, $6\frac{1}{4}$	not lifting 4
Nipper closes at	$8\frac{3}{4}$,, $9\frac{1}{4}$	$10\frac{1}{4}$,, $8\frac{1}{4}$
Clutch wheel in gear at . . .	$0\frac{3}{4}$,, $1\frac{1}{2}$	$0\frac{3}{4}$,, $0\frac{1}{2}$

Those marked with an * in the Egyptian column are

considered very good times, whilst the ones marked with an * in the column for American cotton are settings for the best quality.

There still remain a number of details to be pointed out which have an important bearing upon the work of the comber, but they can, however, only be briefly mentioned here. In the first place, absolute cleanliness of the machine is a condition that cannot be too emphatically insisted upon. It must be clear to all that it is useless making an effort to obtain the very best fibres from any class of cotton, and arranged in a manner calculated to give the strongest result if, through carelessness or ignorance, some of the impurities taken out are allowed to be returned, or even when the effective capability of the machine is somewhat neutralised by the same cause. It is a comparatively easy matter to allow the comber to do its work indifferently, but the greatest care must be exercised if the very best results are desired from it. The continued or intermittent movements of the various parts set up vibrations and currents of air, having a strong tendency to dissipate the delicate fibres or the loose cotton taken out of them as waste. This must be prevented, and we find that arrangements are made with this object in view, so that the collection of the waste and the cleansing of the rollers is performed in some systematic manner.

On referring to Fig. 29, where a section of the comber is illustrated, it will be noticed that a circular brush is shown, the bristles of which are pressed against the needles of the cylinder to the depth of $\frac{1}{8}$ in. to $\frac{1}{4}$ in. Its revolution in the direction indicated freely clears the teeth of the fibres combed out of the cotton, and does it in a way that reduces to a minimum the possibility of fluff flying about. Its speed is greater than that of the cylinder, but the mere

fact of its movement at the point of contact being the same, and also because the angular position of the needles is favourable, a thorough clearing is ensured. It must be understood that the cylinder can only be kept clean if the various rows of needles are perfectly joined up to each other. When even the slightest space exists between the rows of combs, an opportunity is given for accumulations of waste as well as interference with the work of the needles. Much damage is done to cotton through bad workmanship in this respect, and what is technically known as "flocking" is a frequent occurrence. The brush itself, through its continual movement and rubbing against the cylinder, naturally wears to a smaller diameter, and consequently requires readjustment both for position and speed, or otherwise the needles are not cleaned. The cotton on the brush, in its turn, must be taken away, or ultimately the cylinder would pick it up again, so a spiked doffer is used, whose teeth clear the waste from it. The doffer is stripped by means of a vibrating comb in a similar manner to the comb of the card, but, of course, running much more slowly. The waste comes off in a thin fleece or web, and falls into a suitable receptacle arranged to receive it. In some machines the web of waste falls from the doffer upon a slowly revolving shaft, which winds it in the form of a lap, and in this way it is collected in a very neat and compact manner.

What is termed an aspirator is sometimes applied in collecting the comber waste. It consists of a revolving perforated drum or cage set close to the circular brushes in place of the doffer and comb. The cage is fitted with dampers, and a fan draws air through the portions left uncovered and so sucks the fibres from the brushes. These fibres, on the surface of the revolving cage, are carried round

See Appendix for illustration and description of the "Aspirator."

and are deposited on a travelling lattice which conducts them to a coiler at the end of the machine, where they are coiled into a can. At the same time all the dust and loose fibres flying around the comber are sucked into the aspirator, and the machine is kept much cleaner and the air purer by the device; its cost probably keeps it from a general use.

The feed rollers are kept clean by means of a brush pressing against them, whilst the detaching rollers are supplied with movable clearers covered with flannel. In order to prevent the escape of waste, and as a protection also, the cylinder, etc., is carefully covered in by tin casings. These are shown in Fig. 29, at Q and U. They are made so as to be readily removed in case of necessity.

Nasmith's Comber.—A general view of the section of this machine is given in Fig. 46. Some of its features are similar to the Heilmann comber previously described, so a brief description only is necessary in connection with this illustration.

The lap from the ribbon lap machine is placed on the two lap rollers and the sheet of cotton led downwards and underneath the roller B mounted on a plate D. The sheet passes over the edge of this plate, where it is nipped by the nipper E, whilst it is combed by the teeth of the cylinder A. From this point it is taken forward by the detaching roller X after this latter roller has made the overlap or piecing. The rollers Y now continue the forward movement of the sheet, and after it has passed through the usual funnel it is taken forward by the calender rollers "m" in the usual manner.

The plan view Fig. 47 will now enable a few more essential facts to be noted. The driving shaft has a 23^s wheel driving a 90^s wheel on the shaft A or cylinder shaft. On this shaft is fixed the index disc, and on this disc is a

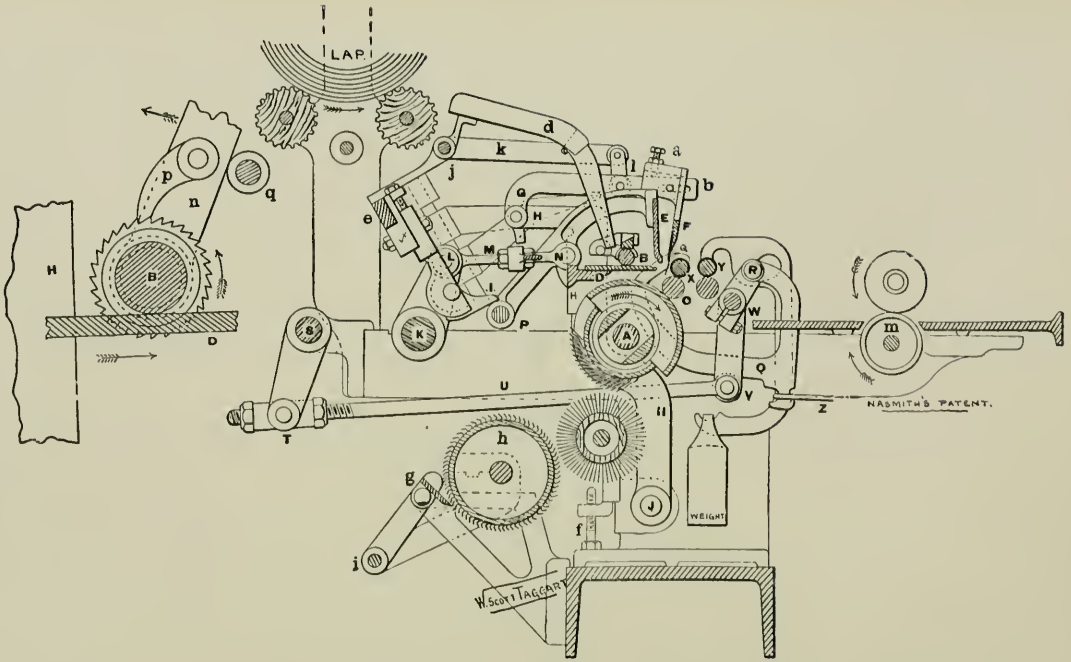


FIG. 46.

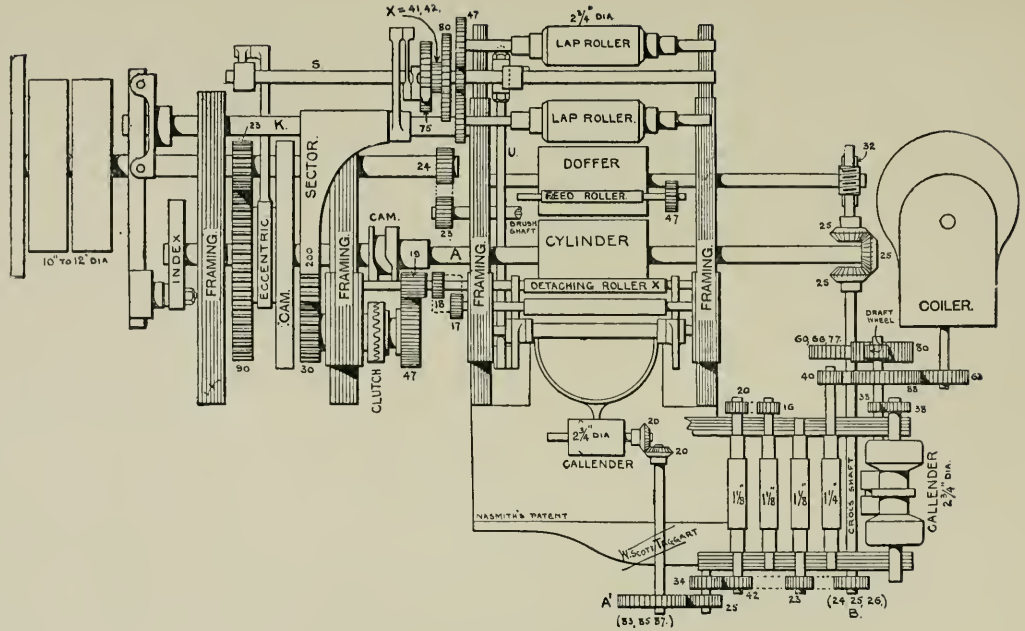
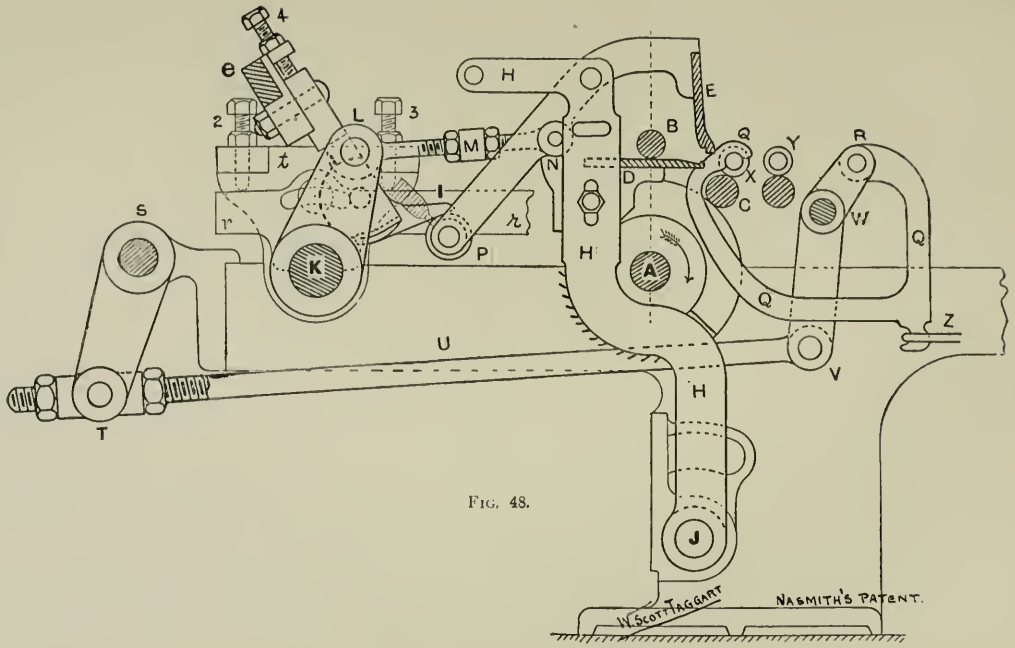

X=41,42.
2¾" DIA.
LAP ROLLER
LAP ROLLER.
DOFFER
FEED ROLLER.
CYLINDER
DETACHING ROLLER X
BRUSH SHAFT
CAM.
SECTOR.
INDEX
FRAMING
ECCENTRIC
CAM.
CLUTCH
10" TO 12" DIA
COILER.
DRAFT WHEEL
CALLENDER
2¾" DIA.
CALLENDER 2¾" DIA.
CROSS SHAFT
NASMITH'S PATENT
W. SCOTT TAGGART
(53, 55 57.)
(24 25 26.)
A
B.

FIG. 47.

pin to which is connected a rod which extends backwards to a lever on the shaft K; the revolution of the index disc acts as a crank and gives a rocking motion to the shaft K. The sector or quadrant rides loosely on K, which thus acts as its centre. An eccentric on the cylinder shaft A gives a rocking motion to the shaft S. The cam on A operates the sector or quadrant through which the backward and forward motions are given to the detaching roller. The rest of the drawing partakes very much of the features with which the reader is already familiar in the Heilmann comber.

By keeping these brief notes of the main features of the machine in mind, the following descriptions of the details will be easily followed. On reference to Fig. 48, a lever H is centred on J; this lever carries a bracket to which a plate D is fixed and a bearing for the roller B. The same bracket is also designed to be coupled up at N by a link or adjusting rod M to a lever L on the rocking shaft K; we can now see that the rocking shaft K will give a to-and-fro movement to the lever H and consequently to the plate D and its roller B. This plate D is the nipper plate and its roller is the feed roller. On the end of the feed roller is a wheel (see small sketch in Fig. 46) and a lever "n" carrying a pawl "p," the whole being carried forward by the lever H. The lever "n" during this movement comes against an adjustable stop "q" and is arrested; but lever H continues to go forward, and as a consequence the pawl "p" acts as a driver to roller B, and causes it to revolve and so feed the sheet of cotton forward in the direction the nipper plate D is moving. The stop "q" can be regulated to give the feed required. This brief description is sufficient to show us that the nipper plate is moved by a simple crank motion, no cam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Q
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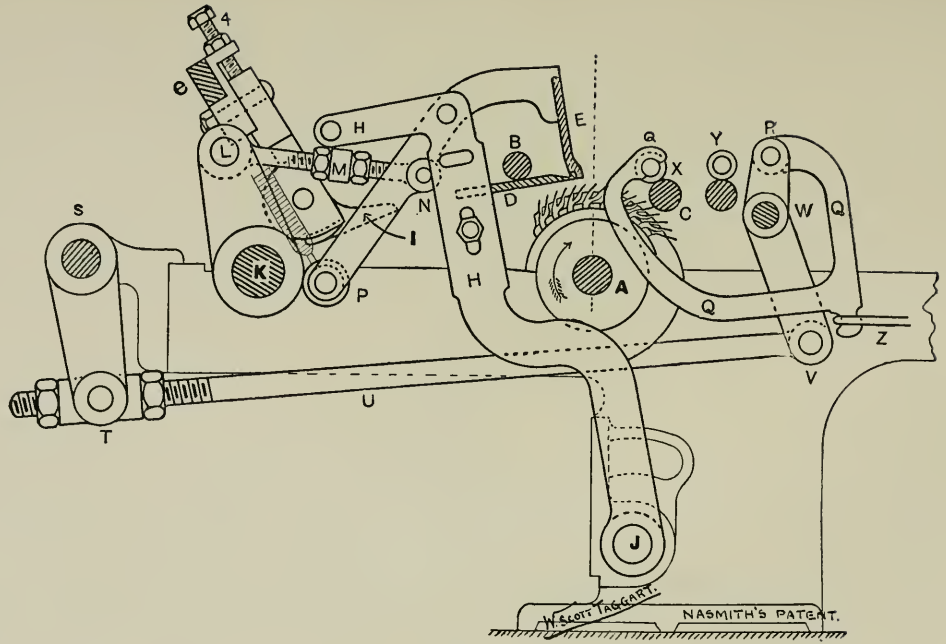
V
H
T
J
W. Scott Taggart
Nasmith's Patent.

Fig. 48.

being required, and that the intermittent feed motion dispenses with the usual Geneva stop or star wheel feed. It will also be noted that there is always a sheet of cotton between the feed roller B and nipper plate D and extending to the edge of the plate. The forward movement of the lever H results in the previously combed length being detached, and a new length is delivered ready for combing; the backward motion of the lever H brings this newly-fed length of cotton into position for the needles of the cylinder to pass through it; but previous to this happening, the top nipper has come down and gripped the projecting cotton against the nipper plate, the grip being metal and metal, for no leather is used. It is interesting to note how the nippers are opened and closed. The top nipper E in Fig. 48 is carried by a lever centred at N and whose other end carries a bowl P. This end of the lever has a spring connected to a fixed part of the framing and its tendency is to close the nippers. As the forward movement of the lever H is finishing the bowl P comes into contact with an inclined foot "1," and so opens the nippers against the pull of the spring. On the return movement the bowl leaves the inclined foot "I" and the spring at once closes the nippers, and the projecting cotton is gripped ready for the combing action. The inclined foot "1" is adjustable, so that the opening and closing of the nippers are easily regulated. The drawing Fig. 49 shows clearly the parts in their backward position, so that a comparison of the two drawings is advisable in following the description. In reference to the top comb a separate sketch is given in Fig. 50 that will convey some idea of its action. It will be seen that the top comb F is carried by a bracket bolted to a lever G that is centred on an extension of the lever H. The movement of H will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V
J
W. Scott Taggart.
NASMITH'S PATENT.

FIG. 49.

therefore carry the top comb to and fro. On the top comb lever is a bowl or pin "14," which, during the backward motion of the lever H, comes into contact with a fixed inclined arm "15" so adjusted that the top comb is raised and clear of the cotton, but on the forward movement nearing completion the bowl passes off the incline and falls, the extent of the lowering of the comb being regulated by the adjusting screws "x." The exact position

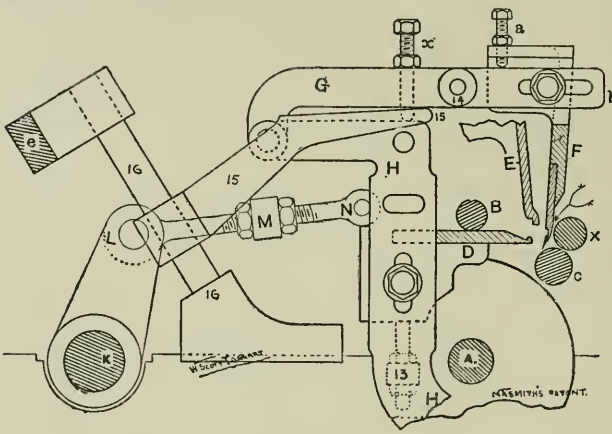


FIG. 50.

of the comb is obtained by the slots "b" in the lever G and the regulating screws "a."

A brief reference may now be made to the detaching mechanism, for which purpose a glance at Fig. 51 may be made. The upper figure shows the cylinder needles combing the cotton, the nippers being closed and in their backward position. Before this combing action is completed, and whilst the finer rows of needles are in action, the nipper plate commences to move forward, and as this movement is in the same direction as the moving needles

the combing action becomes gentle and the fibres freed from strain. In the right hand side figure the needles have passed and the nipper plate has advanced about half

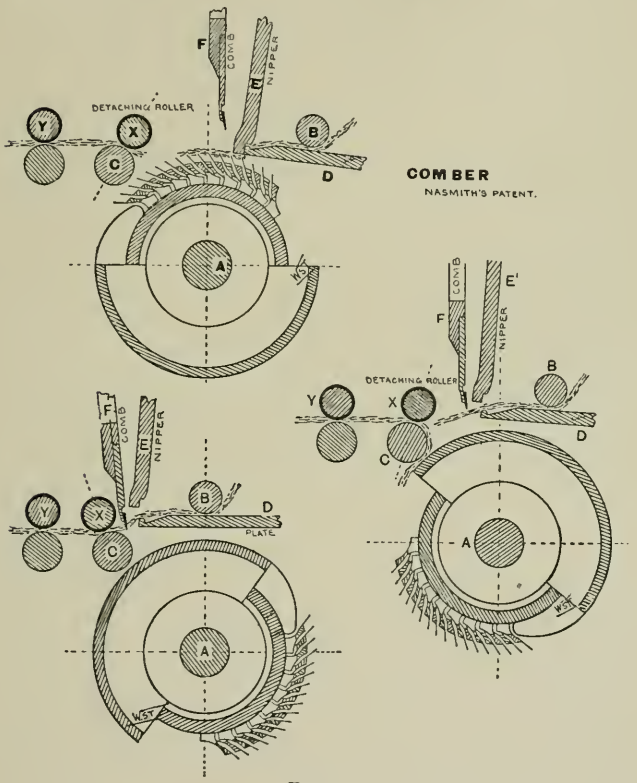


Fig. 51.

way towards the detaching rollers, but just previous to this position, and as the last row of needles pass the detaching rollers, the latter are given their backward motion through the sector or quadrant; this cotton that

has been returned is projected into the space between the needles and the plain segment of the cylinder, and this is the more easily effected by reason of the forward position, relative to the cylinder, of the detaching roller X. The fleece is therefore bent under the bottom roller, and a clear surface of cotton is presented for the newly combed portion to be pieced to it. As this is taking place, the nippers have opened and the released combed cotton rises and points in the direction of the detaching rollers are indicated in the sketch. The top comb in the meantime begins to fall. The detaching rollers now commence to turn forward and the nipper advances, so the combed cotton is laid on the previously returned portion and the whole taken forward until the nipper completes its movement; the top detaching roller is moving away slowly during this period, whilst the nipper is advancing more quickly; the detaching rollers continue to turn a moment longer after the nipper has stopped, and this commences the separation or detaching, an action that is completed when the nipper begins its return movement. It will be seen from this description that the nearness of the grip of the detaching rollers to the nippers is obtained by moving the top detaching roller towards the nippers and then away from them in the delivery; this method entirely dispenses with any contact with the cylinder, so no fluted portion is necessary in this latter organ. A plain circular portion is therefore substituted. Both Figs. 48 and 49 show how the movement of the top detaching roller is effected. The rocking shaft S, through the lever T and connecting rod U, operates the front levers and so brings about the to-and-fro movement of X, the roller being kept in contact with the bottom roller C by a weight hung by chains to the lever Q at Z. The eccentric, on the cylinder

shaft A, and its connection to the rocking shaft S is shown in the sketch Fig. 52. Adjustments are fully provided for in the setting of the roller and its precise moment of action.

A further illustration in Fig. 53 is given to show the method of rocking the nipper shaft K. It is a crank motion, but, owing to the sliding block moving along the lever "r" as the index disc 8 revolves, a variable leverage results, giving a form of quick return motion. The small diagram in Fig. 54 will give some idea of the variable

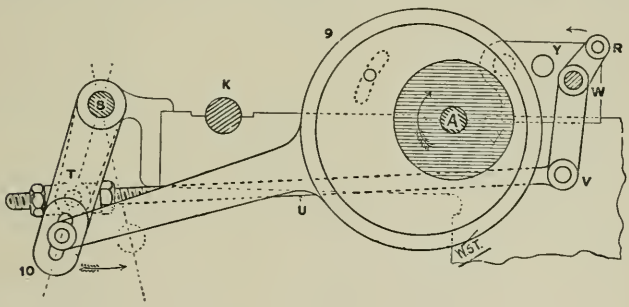


Fig. 52.

character of the movement produced by the crank action; the commencement and ending of both the forward and return stroke are gentle, and all shock is avoided. It is characteristic of the whole machine that all the various operations are free from sudden actions. It remains to point out that this machine, whilst capable of combing a wide range of staple (it will equal the Heilmann in combing the longest Sea Islands cotton with an advantage of double its production under ordinary conditions), finds its greatest value in the combing of shorter stapled cottons, even cotton of $\frac{7}{8}$ inch staple being easily manipulated. This arises chiefly from the fact that the

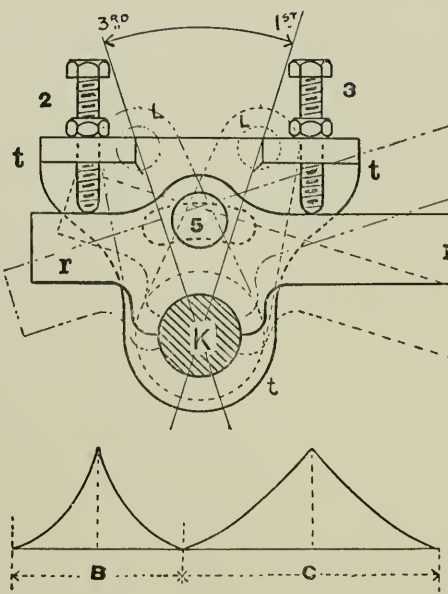


Fig. 54.

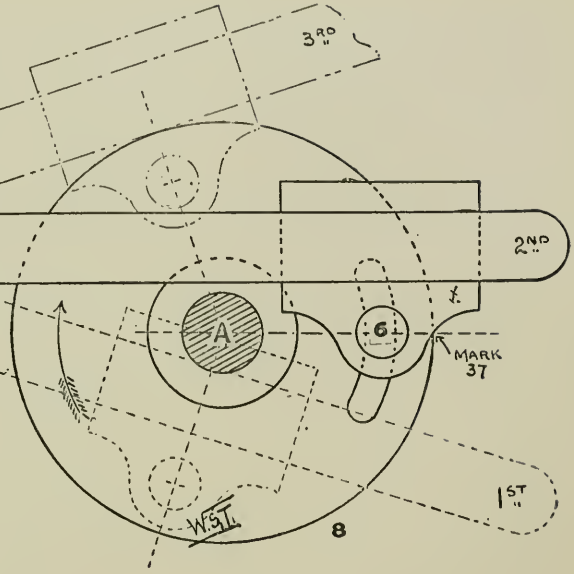


Fig. 53

piecing operation enables a very long piecing to be made, much longer than the length of the staple is itself, and the result gives a uniform and regular sliver not disfigured by the frequent unevenness seen in the Heilmann comber. The waste extracted is well under control and can be brought down to a low percentage on short stapled cotton.

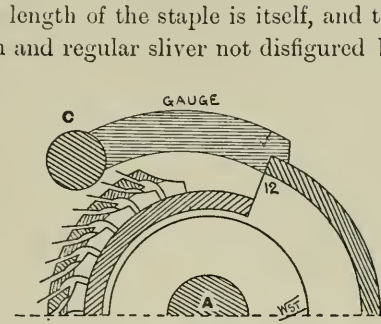


FIG. 55.

The setting of the various parts are readily carried out and the timing of the various operations clearly indicated, so that when the machine is once understood, it presents little difficulty to the practical man.

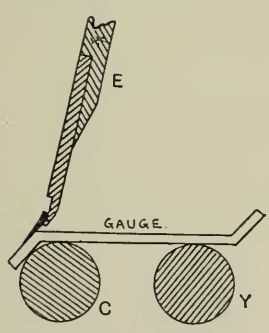


FIG. 56.

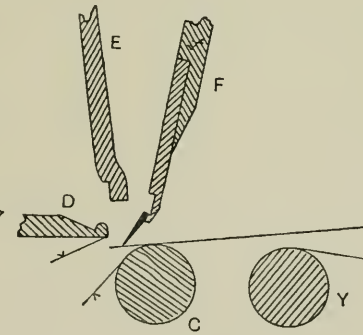


FIG. 57.

Figs. 55, 56, and 57 illustrate the gauges and the chief dimensions requiring attention in setting.

In Fig. 56 the gauge shown is $\frac{1}{16}$ inch and it is used to fix the distance of the top comb from the bottom detaching

roller C, the simple purpose of course being to so set the comb that it is free from any contact with C.

Fig. 57 represents the distance between parts that have an influence on the cleanliness and regularity of fibres of the cotton or the amount of waste taken out. The space between the bottom nipper plate and the surface of the bottom detaching roller is set by means of a stepped gauge marked with numbers 8, 9, 10 up to 16, these numbers representing 32nds, so that we have spaces equal to $\frac{8}{32}$, $\frac{9}{32}$, $\frac{10}{32}$ up to $\frac{16}{32}$, or a variation of settings from $\frac{1}{4}$ to $\frac{1}{2}$ inch. It may be noted that it is extremely difficult to set this distance to the $\frac{1}{4}$ inch gauge. At the same time a compensating setting that has some considerable influence is the distance of the feed roller from the bottom detaching roller, and by moving the feed roller nearer to the front of the bottom nipper less waste is made, and *vice versa*. Of course the greater the distance between the nipper D and the roller C the greater the percentage of waste. The usual settings are given as

$\frac{1}{4}$ inch for American.
$\frac{5}{16}$ to $\frac{5}{8}$ „ Egyptian.
$\frac{5}{8}$ to $\frac{9}{16}$ „ Sea Island.

The gauge used (doctor gauge), that rests under tips of top comb and on the top of roller C, will usually leave a space between the gauge and the top of front detaching roller Y. The greater this distance the larger the percentage of waste taken out, simply because the top comb will enter the web to a greater length of its needles, and so take out more fibres. In some cases, of what may be termed semi-combed yarns made from heavy laps and medium cottons, the top comb is set so that the gauge also rests on the front detaching roller Y.

Weight of Laps.—Width of lap $10\frac{1}{2}$ inches wide.

For longest Sea Island cotton	. .	12 to 18 dwts.	per yard.
,, other ,, ,,	. .	18 ,, 22 ,,	,,
,, Egyptian Cotton	. .	24 ,, 27 ,,	,,
,, American ,,	. .	26 ,, 32 ,,	,,

Speeds.—The speeds are variable for different classes of cotton, but in general they may be taken as follow :—

For best Sea Island cotton .	.	335 revs. per min.,	86 nips per min.
,, other ,, ,,	. .	350 ,, ,,	90 ,,
,, Egyptian cotton	. .	370 ,, ,,	95 ,,
,, American ,,	. .	390 ,, ,,	100 ,,

Production.—This of course depends on several factors, such as speed, weight of lap, and amount of waste extracted. If allowing 15 per cent waste when working a 25 dwt. lap at 100 nips per min., the production of a six-head comber will be about 800 lbs. in a week of 50 hours.

Power.—The Nasmith comber of 6 heads requires about $\frac{3}{4}$ of a horse-power.

An enlarged view of a portion of the Heilmann comber as made by Hetherington's is shown in Fig. 58. Incidentally the drawing illustrates a sliver stop motion which can be applied if necessary. The funnel C is made separate from the sliver tin and carried by a lever centred on a knife edge fulcrum A; when an end breaks or no cotton passes forward, the other end of the lever at B interferes with a vibrating lever D, actuated by an eccentric on the cam shaft through the levers G and F, which releases the slide bar J, unlocks the stop rod K, and so stops the machine. Stop motions ought to be applied to all combers, their extra cost is quickly saved in the quality of work produced.

A further sketch, from the same make of comber, is

given in Fig. 59, which shows **a full can measuring or stop motion.** The bottom calender shaft actuates a lever which through the pawls turns the ratchet wheel, this revolves the worm gearing into the worm wheel, a pin on

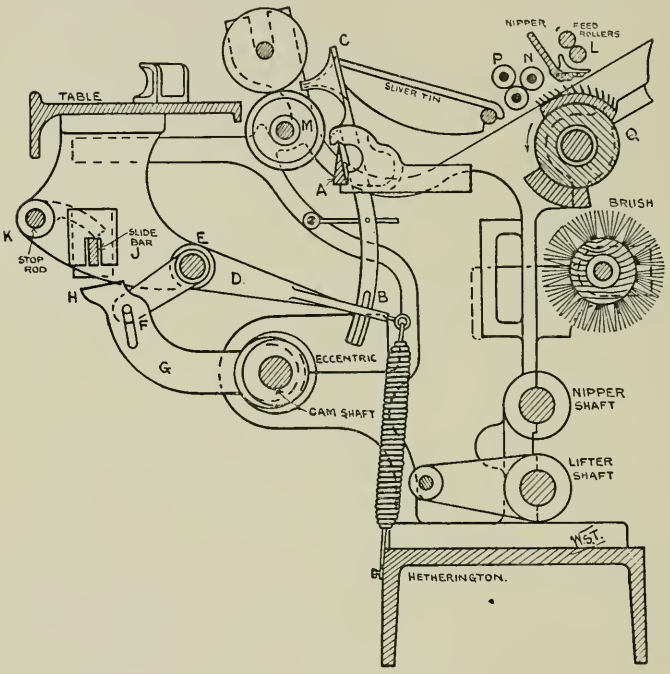


FIG. 58.

the latter is brought into contact with the slide bar and releases the stop rod, thus stopping the machine. Changing the ratchet enables a control of the length of sliver required to be easily obtained.

Whitin Comber.—This comber, made by Howard and Bullough, is an adaptation of the Heilmann comber. In

essentials it is the same machine, but a simplification of various parts enables a higher speed to be run by the cylinder with a corresponding reduction in vibration. A section of the machine is given in Fig. 60, and the various

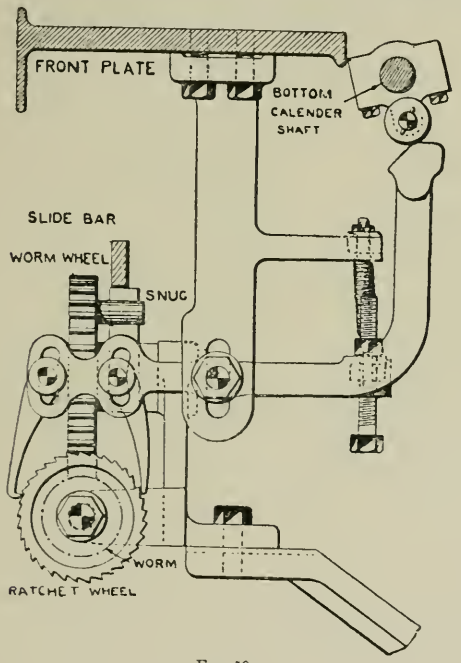


Fig. 59.

features can be followed out by a reference to the names of the parts accompanying the sketch.

It will be noticed that the section could practically be taken as representing the Heilmann comber, and the description of this latter machine is applicable. The improvement or rather the variations from the Heilmann consist chiefly in eliminating the movement of the leather

detaching roller; this roller is kept in one position, so no cam is required. As a consequence the cylinder speed can be greatly increased, so that up to 130 nips per min. are readily obtained. The speed of the cam shaft is kept down by the simple method of making a double cam for

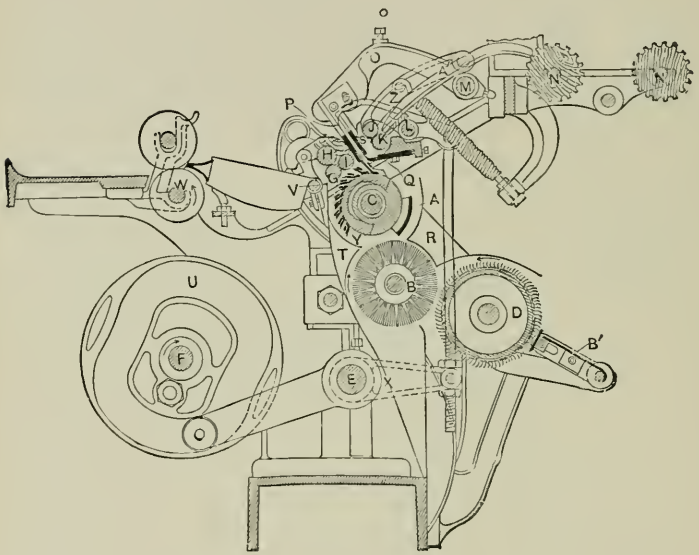


FIG. 60.

A Plain segment.
B Brush.
C Cylinder.
D Doffer.
E Nipper shaft.
F Cam shaft.
G Steel drawing-off or detaching roller.
H Brass detaching roller.
I Leather detaching roller.
J Top feed roller.
K Bottom feed roller.
L Nipper arm fulcrum.
M Top comb shaft.
N Lap roller shaft.
O Top comb arm.
P Top comb.
Q Cushion plate.
R Doffer cover.
S Nipper knife.
T Waste chute.
U Nipper cam.
V Horse-tail holder shaft.
W Calender roller shaft.
X Nipper shaft lever.
Y Half lap.
Z Top feed roller saddle.
A_1 Lap plate.
B_1 Waste packer.

operating the nipper. The cycle of actions in combing the cotton can easily be understood on reference to Figs. 60A,

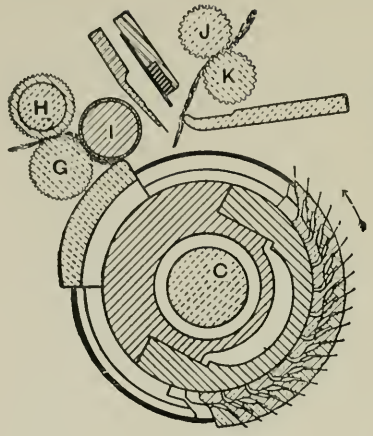


FIG. 60A.
Showing portion of lap advancing prior to combing.

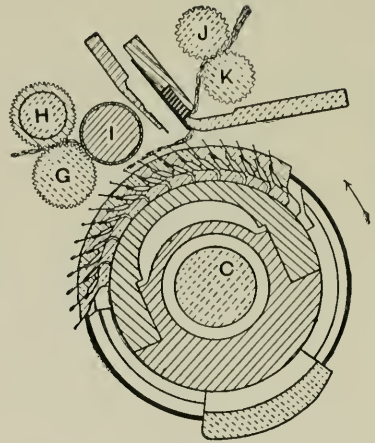


FIG. 60B.
Cylinder combs in operation.

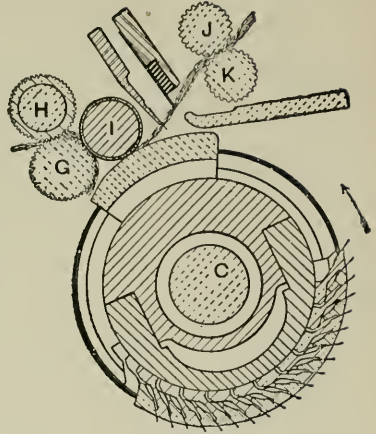


FIG. 60C.
Top comb in operation.

60B, and 60C, which show the various organs at different stages of their movements. In general this comber is applicable for all purposes for which the Heilmann is used, whilst in addition it is also well adapted for reclaiming the large proportion of good fibres found in card strips, these latter amounting to sometimes 60 per cent of the waste.

The setting of this comber follows somewhat similar lines to that of the Heilmann. For ordinary purposes it will be found that the nippers close at $11\frac{1}{2}$ on index wheel. The detaching roller moves forward at 6, and the feed roller moves at from $3\frac{1}{2}$ to $6\frac{1}{2}$ according to the percentage of waste required to be extracted. The increase of waste may be obtained by setting the top comb closer, by feeding later, by putting more angle on the nipper knife and top comb. Weights of laps weigh from 400 to 550 grains per yard.

The production varies from 700 to 900 lbs. per week of 55 working hours.

All the usual motions for reducing wear and tear, stop motions, taking up wear of brushes and running at correct speeds, collecting waste, etc., are applicable to this machine as to the other combers described.

Nippers.—The nippers previously described are made by most firms who manufacture combers, but a special form has been adopted by Dobson and Barlow's which has advantages. An illustration is given in Fig. 61. It will be noticed that the nipper knife is covered with leather or other soft material. This simple device enables the setting of the nipper to the needles of the cylinder to be extremely fine; there is no danger of the needles being destroyed by contact with the metal as frequently happens in the previous types of nippers, so that, from this point of view alone, the new method is a means of saving considerable

time and money in the course of a year. In addition to its protective advantages, the finer setting enables a thicker lap to be used and a corresponding increase in production ranging from 30 to 60 per cent.

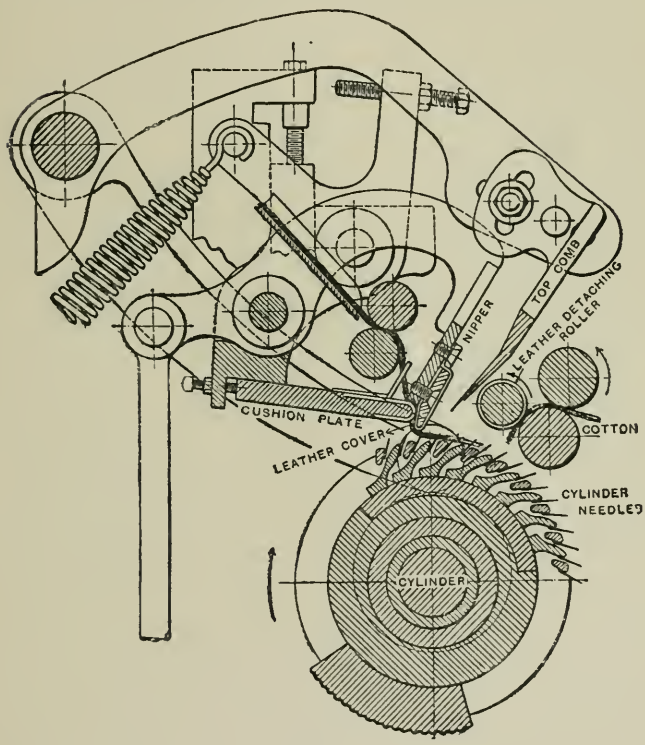


FIG. 61.

In Fig. 62 is presented a part plan of the comber, arranged with the object of showing the whole of the driving mechanism and gearing. From it can be traced the method of driving each separate action, and by using

it also for reference, when reading the previous description of the machine, a more intelligent idea of its motions will probably be obtained. It will be noticed that one complete head is shown, and part of another. If the whole of the comber had been drawn in plan there would have simply been a repetition of the first set of rollers and cylinder to six or eight heads, each head of which works precisely alike, and delivers its own combed sliver. These slivers travel along a smooth, polished plate, parallel to the length of the machine, to the end, where they are passed through a draw-box, consisting usually of three lines of rollers, as shown in the drawing. At this point the combined slivers undergo a draft, which, of course, varies according to the purpose required. From the draw-box it continues its course, after passing through a pair of small calender rollers, to the coiler, a full section of which is shown on the right of the illustration.

The driving of the machine takes place through the pulley shown on the left. This pulley is keyed on a short shaft firmly carried by the framing, so that no vibration can possibly exist. Its motion is balanced by a fly-wheel in order to prevent fluctuation of speed, owing to the intermittent movement of some of its actions. On the driving shaft is fixed a pinion, which, in the single comber, drives direct on to the cylinder through a large wheel of 80 teeth. This wheel, in its turn, drives the cam shaft through a similar wheel, so that the cylinder and cam shaft revolve at the same speed. On the cam shaft is shown the disposition of the various cams, etc., an enlarged view of a portion of which has been given in a previous drawing. The calender roller is also driven from this shaft by worm and worm-wheel arrangement.

The feed roller is driven from the cylinder shaft, as

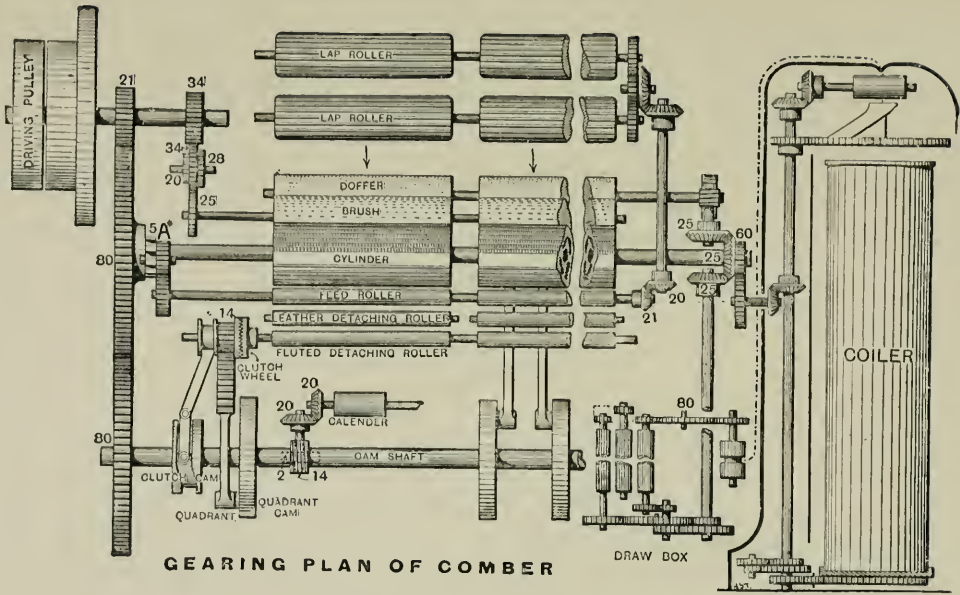

LAP ROLLER
LAP ROLLER
DRIVING PULLEY
21
34
34
28
20
25
DOFFER
BRUSH
5A
80
CYLINDER
FEED ROLLER
LEATHER DETACHING ROLLER
FLUTED DETACHING ROLLER
14
CLUTCH WHEEL
20
20
CALENDER
80
CLUTCH CAM
CAM SHAFT
2
14
QUADRANT
QUADRANT CAM
25
60
25
25
20
21
80
COILER
DRAW BOX
GEARING PLAN OF COMBER

Fig. 62.

already explained, by the star wheel and gearing at A. A is a change place in order to alter the feed according to the length of the staple being worked. As pointed out, the feed roller drives the lap roller, the gearing of which is clearly shown in the sketch.

The brush is driven from the driving shaft through carriers, which may be worked as a simple carrier, as represented in Fig. 62, or as a compound carrier, by simply changing the wheel into which the 34's on the driving shaft gear.

On the opposite end of the cylinder shaft to the driving pulley is an arrangement of gearing by means of which the draw-box is driven, and also the coiler and doffer. Very little changing is done on the comber in regard to the gearing after it has left the maker's hand. The only places where this is effected are the feed wheel A and a change in the draw-box, but this latter is not often changed. Changes, of course, can be made to suit almost any special conditions, but these do not come under the general head of change places, and consequently they cannot be dealt with here.

"Calculations."[1]—The following particulars of the gearing will enable the necessary calculations to be made:—

Driving shaft wheel	21 teeth
Cylinder index wheel	80 ,,
Cam shaft wheel	80 ,,
Cylinder wheel	60 ,,
Coiler wheel	59 ,,
Block wheel	40 ,,
Front roller wheel	22 ,,
,, ,, ,,	34 ,,
Compound carrier in draw-box	40 ,, / 45 ,,

[1] Several makes of combers are fully illustrated in gearing plans and the calculations given for them in the author's book on *Cotton Spinning Calculations*.

Side shaft wheel	14 teeth
Back roller wheel	50 ,,
Diameter of back roller	$1\frac{3}{8}$ in.
Diameter of bottom block in draw-box	$2\frac{3}{4}$,,
Diameter of calender in coiler	2 ,,
Coiler driving bevel	22 teeth
Coiler bevel	22 ,,
Star wheel	5 ,,
Cam shaft worm	double
Cam shaft worm wheel	14 teeth
Calender mitre bevels	20 ,,
Diameter of feed roller	$\frac{3}{4}$ in.
Diameter of calender roller	$2\frac{3}{4}$,,
Feed wheel	18 teeth
Feed roller wheel	38 ,,

The above particulars are taken from a machine working fine Egyptian cotton.

$$\text{Draft of draw-box} = \frac{22 \times 40 \times 50 \times 50 \times 2\frac{3}{4} \text{ in.}}{40 \times 34 \times 45 \times 14 \times 1\frac{3}{8} \text{ in.}} = 5{\cdot}13.$$

$$\left.\begin{array}{l}\text{Draft from the calender in} \\ \text{draw-box to the coiler}\end{array}\right\} = \frac{40 \times 34 \times 45 \times 60 \times 2 \text{ in.}}{22 \times 40 \times 50 \times 59 \times 2\frac{3}{4} \text{ in.}} = 1{\cdot}03.$$

$$\left.\begin{array}{l}\text{Draft from the feed roller} \\ \text{to the calender block}\end{array}\right\} = \frac{38 \times 5 \times 2 \times 20 \times 2\frac{3}{4} \text{ in.}}{18 \times 1 \times 14 \times 20 \times \frac{3}{4} \text{ in.}} = 5{\cdot}52.$$

$$\text{Total draft of machine} = 5{\cdot}13 \times 1{\cdot}01 \times 5{\cdot}52 = 28{\cdot}6.$$

The total draft can also be obtained by finding the draft in one operation between the feed roller and the draw-box block, and multiplying it by the draft between the draw-box and the coiler. For instance—

$$\frac{38 \times 5 \times 50 \times 40 \times 22 \times 2\frac{3}{4} \text{ in.}}{18 \times 1 \times 45 \times 34 \times 40 \times \frac{3}{4} \text{ in.}} = 27{\cdot}826.$$

$$27{\cdot}826 \times 1{\cdot}03 = 28{\cdot}6 \text{ total draft.}$$

or

$$\frac{38 \times 5 \times 60 \times 2}{18 \times 1 \times 59 \times \frac{3}{4}} = 28{\cdot}6 \text{ total draft.}$$

In calculating draft it frequently happens that the actual draft differs from the results arrived at by calculation. This occurs chiefly in connection with machines dealing with slivers, such as the draw frame, sliver lap machine, ribbon lap machine, and comber. This difference must arise, because, for calculation purposes, the exact diameter of the bottom roller is taken as the basis. If the top roller were driven positively and exactly the same surface speed as the bottom roller there would be no difference, but since the top roller is driven by the bottom roller through the layer of cotton between them, and the top roller is weighted, the thickness of the cotton passing through has some influence on the draft, and brings about a difference between the calculated draft and the actual draft. The two factors of thickness of slivers and weighting of the top rollers must be taken into consideration when dealing with the question of draft. An important factor that sometimes arises in this connection is the speed of the front roller. As a rule it is presumed that the top roller will be driven regularly and easily by the bottom roller through the friction of the fibres between them, but it will be clearly seen that this cannot always take place. If the weighting is not carefully adjusted to suit both the sliver and the speed, the fibres in contact with the bottom roller will travel forward quicker than the fibres in contact with the top roller, and there will naturally be a tearing away of fibres, thus giving rise to the condition termed "spewing" as the sliver emerges from the nip of the rollers.

Comber.—Difference in weighting the leather detach roller alters the waste. 32 lbs. on detach roller gave 9%, changed to 16 lbs. gave 12%, due to less grip and probably long fibres taken out.

To find Percentage of Waste.—Have doffer comb at

the bottom of its swing, now remove all waste at the back up to the doffer comb. Break the sliver at the draw-box calender rollers. Work the machine for, say, 40 nips, leaving the doffer comb at its lowest point. Now weigh respectively the sliver and the waste made. The two added will equal the original cotton, and the waste will represent a percentage of this total. For instance—

Good sliver = 60 grains
Waste = 15 ,,
Total cotton = 75 grains.

If 75 grains of lap have 15 grains of waste,

Then 100 grains of lap have $\frac{15 \times 100}{75}$ grains of waste,

$\therefore \frac{15 \times 100}{75} = 20$ per cent of waste taken out.

CHAPTER III

FLY-FRAMES.

Object of Fly-Frames.—Hitherto, the processes described here have all been directed towards obtaining a uniform strand of cotton, free from impurities, and whose component fibres approach within a reasonable degree of equality in their length. The actions that have been employed to produce this result are Beating, Combing, Drawing, and Doubling, and the cotton in being subjected thereto has been reduced from an irregular mass of tangled fibres to, comparatively speaking, a condition of regularity and uniformity.

The next process is one primarily intended simply as a continuation of the Drawing process, with or without the combination of Doubling. Owing, however, to the extreme delicacy of the sliver, any further reduction of its diameter would make it so weak as to practically prevent its further treatment, unless such reduction were accompanied by some action which strengthened it, so that it could withstand the strains to which it would be subjected when undergoing the next steps in the process. In addition to this, we can easily understand, from what we have seen of the coiler, that the use of this for coiling a much finer roving or sliver would be a very clumsy

NOTE.—A very complete set of practical notes on these machines will be found in the author's book, *Cotton Mill Management.*

method, and consequently a slight twist is given to the reduced sliver, and it is then wound upon a bobbin. The small amount of twist given to the attenuated and extremely loose sliver is sufficient to give it the necessary strength to enable it to be built up in the form of a bobbin, in which condition it is very convenient for further treatment. The drawing-out or reduction of the sliver, from the diameter as it exists when passing through the drawing frame to a diameter suitable for the process of spinning, is so great, and results in such a weak sliver or roving, that a very delicate and gradual operation must be exercised. The steps, by means of which the reduction is made, depend upon the degree of fineness required in the resultant yarn, and consequently they vary in number.

The machines used for effecting the attenuation of the sliver are called by the different names of **Fly-Frames, Roving Frames,** and **Speeders:** and according as one or more of these are used, we get specific names for the machines in each step. For instance, the first fly-frame used after the draw-frame is called a **Slubbing Frame;** following this is the **Intermediate Frame,** and then the **Roving Frame;** after which (for fine spinning) a finer roving frame is used, called a **Jack Frame.** The order of these machines for their several purposes will be seen on referring back to p. 48, vol. ii., where their sequence was shown for various numbers; and it will also be noticed that as the numbers or counts increase, so do the number of sets or passages of fly-frames. The objects of each machine are exactly the same, and so for all practical purposes their structure and mechanism are alike, the only difference being in the strength and dimensions of the various parts.

The necessity that arises at this stage in the building

of the roving or sliver in the form of a bobbin, also introduces in its wake complications of mechanism for automatically performing it, and these give to cotton machinery, from the mechanical point of view, one of its greatest sources of interest.

The bobbin is made by winding the sliver round a wooden cylinder in layers until a suitable diameter is obtained. When finished it has the appearance of a cylinder with its ends tapered, in which condition it is the more readily, and with the least possibility of injury to itself, taken from one machine to another. The various problems connected with the building of the bobbin will be dealt with as thoroughly as possible as the description proceeds. It is sufficient at this stage to mention that the placing of layer upon layer of roving on the bobbin necessitates a varying speed being given to it in the fly-frames, the delivery of sliver during the process being constant. There is also a variation in the length of transverse, to give the tapered character to the bobbin. These two motions present some very ingenious and mechanical problems, which it is advisable should be thoroughly understood, if more than a mere superficial knowledge of the subject is to be obtained.

In regard to the twist put into the roving, it will be found that twisting is an inevitable consequence of this mode of forming a bobbin by means of a flyer; but arrangements are made in the machine whereby the amount—within certain limits—can be carefully regulated. For all practical purposes the twist or turns per inch is largely a question of experience, and depends upon several factors, which must always be taken into account when deciding upon this important point. It is, however, never more than might be correctly described as a "slight twist"; for

it must be clearly understood that the merest excess of twist in the roving would prevent any further drawing in the following machines. From this we can readily comprehend that, although the twisting is taken advantage of for giving cohesion to the fibres during the winding operation, the ultimate purpose of the yarn must be kept in view, and the twists must also be arranged so that the effectiveness of any future drawing action will not be destroyed. In following the passage of the cotton through the several fly-frames it will be remarked that the reduction of the sliver takes place gradually, a little at each frame. The exact amount of the draft, of course, depends upon the cotton used, and also upon the numbers to be spun, but the accompanying table will convey an idea of the usual course adopted in most mills :—

Drafts for Indian and American Cotton.

	Draft.
Slubbing Frame	4 to 5
Intermediate Frame	5 ,, 6
Roving Frame	$5\frac{1}{2}$,, $6\frac{1}{2}$

Drafts for Egyptian and Sea Island Cotton.

	Draft.
Slubbing Frame	5 to $5\frac{1}{2}$
Intermediate Frame	$5\frac{1}{2}$,, $6\frac{1}{2}$
Roving Frame	$6\frac{1}{2}$,, 8
Jack Frame	$5\frac{1}{2}$ upwards

There are many variations in drafts introduced in order to obtain identical results, and this is so true that probably no two men would use the same drafts in spinning similar classes of yarn. The reason for this is almost apparent: the number of machines through which the cotton must pass, readily permits a give-and-take policy in the arrangements of the drafts, and many men would alter the drafts of one or two machines only, instead of making a change on all the machines—provided, of course, there was nothing

excessive in such a method. It is, however, always advisable to let each machine do its own share in the work of making the roving finer: this will mean more time and labour in making changes, but better results are certain to be obtained by the extra trouble involved. It has been remarked that very little difference exists between the four passages of fly-frames, and what difference does exist is caused by alterations in the diameter of the full bobbins and in their lengths. In the slubber the bobbins are large and long; they get smaller as the roving is made finer, until in the Jack we have a bobbin with only one-quarter to one-fifth the amount of roving on it. The following table presents the usual practice in regard to this feature, but it must be understood that slight variations exist on either side of the dimensions given:—

Cotton.	Slubber.		Intermediate.		Roving.		Jack.	
	Dia.	Lift.	Dia.	Lift.	Dia.	Lift.	Dia.	Lift.
	in.	in.	in.	in.	in.	in.	in.	in.
Indian and Low American . .	$5\frac{3}{4}$	10	$4\frac{1}{2}$	10	$3\frac{1}{2}$	7	...	...
American and Low Egyptian .	$5\frac{1}{2}$	10	$4\frac{1}{2}$	10	$3\frac{1}{2}$	7	...	...
Good Egyptian and Sea Islands	$5\frac{1}{2}$	10	$4\frac{1}{2}$	10	$3\frac{1}{2}$	8	...	...
American . . .	...	...	...	...	...	...	$2\frac{3}{4}$	7
Egyptian . . .	...	...	...	...	...	...	$2\frac{3}{4}$	7
Sea Island . .	...	...	...	...	...	...	$2\frac{1}{2}$	7

Description of Fly-Frame.—In the accompanying sketch (Fig. 63) a transverse section through a fly-frame is given. As will be seen, it is not complete, but a sufficient portion of the machine is shown to enable its essential

features to be pointed out and explained; a full detailed examination of its actions will afterwards be made, and, as

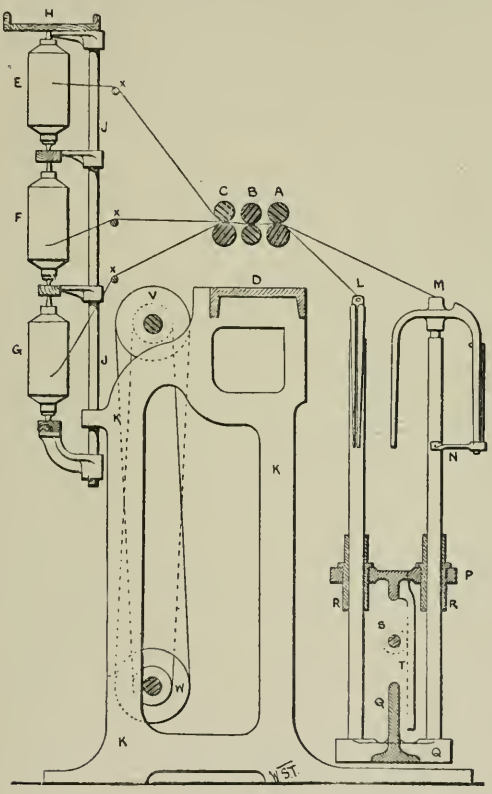


FIG. 63.

far as possible, illustrated by numerous drawings and diagrams.

On reference to the drawing (Fig. 63) it will be noticed that the sliver is fed to the rollers at the back, from bobbins, placed in a suitable structure called a creel. (This name is

given to almost all arrangements in cotton machinery by which bobbins are carried.) It must, however, be pointed out that in the slubbing frame this creel is not necessary, because in that case the cans from the drawing frames stand behind the machine, and their slivers are taken over a slowly revolving tin drum and passed on to the rollers. When bobbins are formed, a creel becomes requisite for carrying them, and its exact form varies according to the number of bobbins it has to accommodate, and also the number of heights in which it is convenient to make it. In the sketch a single row is used, and it is made in three heights. The full bobbins are taken from the previous machine, and placed on wooden skewers; a shoulder on the skewer forms a resting-place for the bobbin, so that they are prevented from touching the long wooden rails, which go the full length of the machine, and which constitute the chief features of the creel. These skewers are pointed at each end. The upper portion enters the rail, and rests in a hole protected by a small iron ring to reduce friction, whilst the lower end rests upon a small recessed cup-shaped porcelain step, well glazed, so as to offer as little resistance as possible to the revolution of the bobbin as the sliver is drawn from it. As a rule, in modern mills, the rails of the creel are really made of long lengths of thin angle iron, with the wooden part screwed to them on their under side. This gives a much stronger creel, and one that is practically indestructible. The rails are carried by brackets fixed to upright rods J, which are in their turn securely fastened to the spring pieces of the machine. This arrangement of the creel enables the distance apart of the rails to be readily adjusted. The top of the creel is made so that a stock of full bobbins can be placed there ready for immediate use.

The rovings are taken from the bobbins E, F, and G, and passing over the guide rods X are led to the three lines of rollers A, B, and C. In going through these they are subject to a drawing action the same as in the draw-frame, and to this extent it is simply a continuation of that process. The amount of this draft for general purposes has already been given, see p. 120.

We are now in a position to see the need for the introduction of twist into the roving. The strain upon the sliver as the back roller takes it forward is considerable, when we take into account that it has to pull round the full bobbins in order to unwind itself, and so an additional cohesive power is given to it by twisting, in which the fibres are rather more firmly bound together, but not sufficiently so to interfere with the further drawing to which it must submit in the next operation.

The drawn-out sliver or roving is taken from the rollers and threaded through the flyers L M, and wound upon bobbins which loosely fit the long spindles that carry the flyers. The bobbins are all driven separately and independently of the spindles, whilst the spindles also are individually driven. The spindle consists of a long steel rod, whose diameter varies from $\frac{7}{8}$ in. in slubbing frames to $\frac{9}{16}$ in. in jack or fine roving frames. Its length also varies according to the machine. In consequence of the speed at which it revolves, it requires to be well supported in suitable bearings, so as to prevent vibration and reduce friction as much as possible. It is, therefore, carried in a footstep bearing at Q, and in a bolster bearing at P. The bearings at these points are made as long as possible by means of the collars R R firmly fixed to the top rail P. These collars are generally made in two lengths, and hence they are usually known by the terms of "long" and

"short" collars. The top rail P has resting upon it all the bobbins of the machine. Since the spindles and flyers are stationary so far as vertical movement is concerned, the bobbins must be given this motion in order to have wound upon them the roving which passes through the flyer. With this object in view, the rail P is given a perpendicular movement, which constitutes the lift or traverse of the machine, and defines the length of the bobbin. It receives the motion through a rack T and wheel S, the rack being fastened to the rail and the wheel obtaining its movement through suitable gearing from the driving shaft.

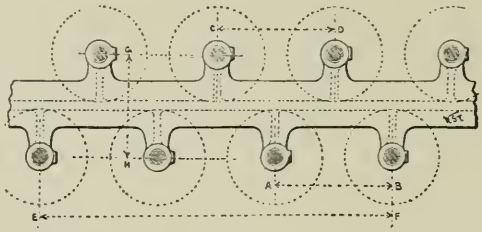


FIG. 64.

Arrangement of Spindles.—All fly-frames are made with two rows of spindles, so disposed as to economise space and yet obtain a maximum number of spindles in a given length. Fig. 64 is given as an illustration of this, and from it we see that they are arranged in a zig-zag order—in many cases regularly so, but in other makes of machines the back row is not placed exactly midway between the centres in the front row, but a little to one side, the object being to facilitate doffing, etc. The "**space**" of the spindles is the distance from the centre of one to the centre of the next, as at A B or C D, whether we take the front or back row for the measurement. In many

cases, however, the word "space" is replaced by the word "**gauge**," and instead of expressing the space of the spindles the machine is spoken of as having a certain "gauge." This to a certain extent is an advantage, because both rows of spindles are taken into account when the number or length of the machine is required, whilst in the first case only one row is expressed, and so it is necessary to double or half, as the case may be. In the sketch the "gauge" of the spindles would be denoted by saying that there are six spindles in the distance E F. This measurement, it will be seen, includes three spindles in each row.

The following will show the two methods of denoting the space of spindle :—

Distance of spindle from centre to centre	in. $5\frac{1}{2}$	in. $5\frac{3}{4}$	in. 6	in. $6\frac{1}{4}$	in. $6\frac{1}{2}$	in. 7
Or equal to 6 spindles in . . .	$16\frac{1}{2}$	$17\frac{1}{4}$	18	$18\frac{3}{4}$	$19\frac{1}{2}$	21

Roller Stands.—A general view of the roller stand and the method of setting the rollers is given in the accompanying drawing (Fig. 65). On reference to it, it will be noted that the stand itself is a fixture on the roller beam N, and that it carries the front roller D. The other two lines of rollers are carried by separate bearings E and F, which are so arranged on the main stand that their distance from each other can be adjusted so as to suit various lengths of staple, thus giving every facility for setting; after which they are readily fixed in position by means of the set screw. The recess G is occupied by the traverse rod, which moves the roving to and fro along the roller with the object of preventing an undue wear of the leather on the top roller. The top rollers—made either with a single or double boss, and also with or without loose bosses—are covered with leather in the usual way, and carried by an arrangement of cap bars, these latter not being used as

bearings, but simply as side supports for the ends of the rollers. They are made so as to enable the rollers to be readily taken out, and also so that any given set of bars may be bodily removed or turned over out of the way of the bottom rollers. It was formerly the practice to make the cap bars of cast-iron, but difficulties were experienced in several directions when so made, there being irregularities in the spaces, owing to moulding and casting, a slight damage necessitating an entirely new cap bar; there was

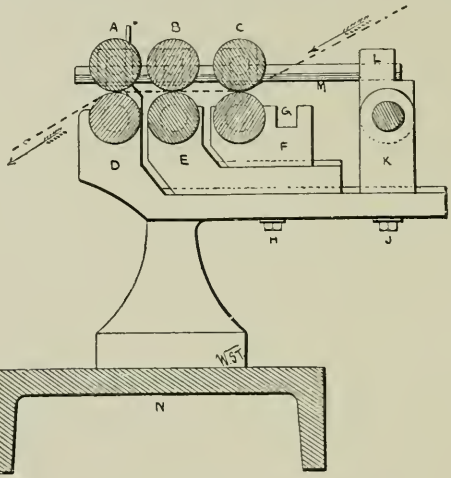


FIG. 65.

also a lack of simplicity in the adjustment of the slides for the different rollers, and, owing to the strain caused by screwing the loose parts together, various other parts were twisted out of truth. Very great care in the making can obviate some of these faults, and irregularities are the more easily rectified by means of milling machines, so that some makers still adhere to this method of making the cap

bars. Another system, now extensively followed, is that shown in Figs. 65 and 66. Here a support K is fixed to the roller stand, and carries a shaft or stud F, and on this shaft, at the necessary intervals, are fixed small brackets E (Fig. 66). These carry a long finger D of a pentagonal section (see H), and on it are threaded the cap nebs, A, B, and C, which form the supports for the top rollers. The hole through the nebs is similar to the section of the finger, and consequently they are prevented from turning, and, in addition, no side strain is introduced, because they are firmly screwed in position by set-screws bearing on a perfectly flat surface of the finger. The projections on A serve the purpose of a rest for the flat or clearers on the

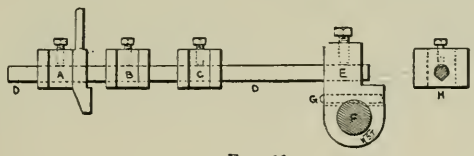


FIG. 66.

upper part, and, on the lower one, adjust the centre vertically for the top rollers. As it may easily happen that carelessness or other causes might allow the finger or nebs to fall on the fluted rollers, precautions are necessary, and a slight recess is cut in F, and a tapered pin driven into the bracket E, this pin effectively preventing any twisting of the bracket, and also holding it securely in position.

Roller Weights.—A front view of the rollers and stands is given in Fig. 67. The sketch shows four spindles to a box, *i.e.* between two roller stands rovings are delivered, which supply four spindles. Double-boss top rollers are used, and the cap bars would be placed to support the pivoted ends at L M, J K, and N P. The weights applied to give the required pressure between the rollers would in

each case hang from G H. These weights, like many other details of cotton machinery, vary in their amount, but the following may be taken as representing the usual practice :—

	Front. lbs.	Middle. lbs.	Back. lbs.
Slubbing Frame	18	14	10
Intermediate Frame . . .	14	10	8
Roving Frame, single boss . .	10	8	6
,, ,, double boss . .	18	14	12

In Roving and Jack Frames it is usual to have the back and middle rollers self-weighted, *i.e.* the weight of the

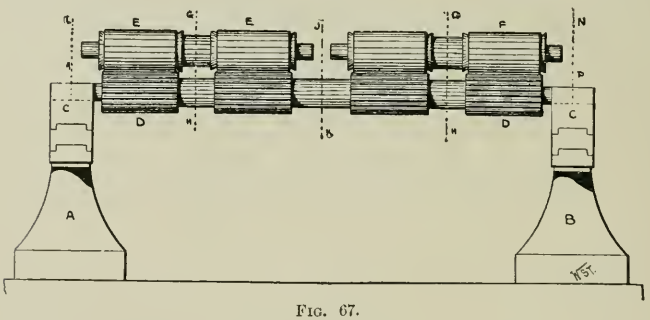


FIG. 67.

rollers themselves is sufficient for the purpose, in which case the back roller is made much larger in diameter, as will be seen on reference to the next sketch.

Diameter and setting of Rollers.—In this diagram (Fig. 68) a representation is given of the usual diameters, and the distance apart of fly-frame rollers for various classes of cotton ; but it must be impressed upon the reader that no hard and fast line is to be drawn in respect to the dimensions given, and it will always be necessary to exercise judgment upon the special characteristics and staple of the cotton worked.[1]

[1] See Vol. III. for fuller details of rollers, etc.

A	Indian cotton	Slubbing Frame.
B	American cotton	
C	Egyptian and Sea Island cotton .	
D	Indian cotton	Intermediate Frame.
E	American cotton	
F	Egyptian and Sea Island cotton .	
G	American cotton	Roving and Jack Frame.
H	Egyptian and Sea Island cotton .	

NOTE.—In the jack frame the distances apart of the rollers will be slightly greater than in the roving frame. It must also be observed that the top roller diameters are for the rollers when uncovered.

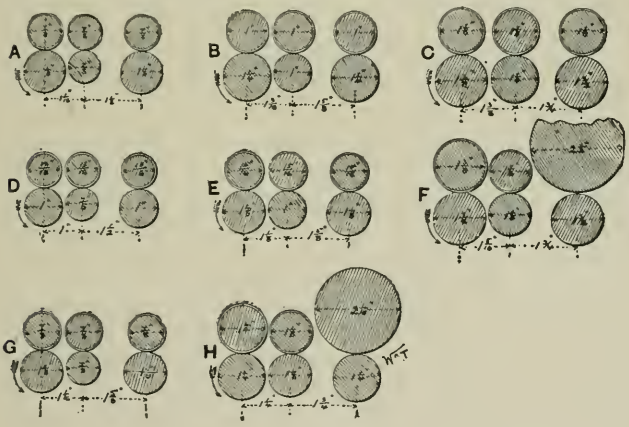


FIG. 68.

A general idea of the number of flutes in fly-frame rollers may be obtained from the following:—

$1\frac{1}{8}$ in. dia. =54. $1\frac{1}{4}$ in. dia. =60. $1\frac{3}{8}$ in. dia. =65.

Twisting.—It has been remarked that directly the roving emerges from the front roller it undergoes a twisting operation—a somewhat necessary effect of winding it upon a bobbin by means of a flyer. We can now examine this action in detail. When it is desired to put twist into any arrangement of fibres, etc., the essential

condition is that one end must be held while the other is twisted. This statement is so expressed because in cotton spinning machinery the definition fits in with actual practice. A better method of defining how twist is produced may be by stating that one end of the substance must be revolved round its axis at a quicker rate than the other end, and in the same or the opposite direction. Even this definition might be simplified to some minds by saying that the angular velocities of each end must vary, when measured in the same direction, in order to produce twist or to cause an intertwining of the component parts of the substance. In the example of the flyer, this condition is carried out in a very simple manner. Figs. 69 and 70 are presented to illustrate the description of its form and action. The spindle upon which the flyer is placed is a long steel rod carried by a footstep and a bolster. At the footstep end it is slightly reduced in diameter, as shown in Fig. 71, and its bearing is usually a recess fitted with a brass bottom; or it can be made self-lubricating with a loose brass bottom part. In the sketch, however, an improvement is shown that enables the oiling of the spindle footsteps to be done very effectively, and with a minimum of trouble, and at the same time a reservoir keeps the bearing well lubricated. The spindle is grooved for a short distance above the point where the small bevel is fixed, and a slight recess is cut in the upper part of the bevel wheel. By oiling at this point the oil descends by the groove to the reservoir, and in this way the necessity of going through the trouble of lifting the spindles is dispensed with. As shown in the drawing, it is well-nigh impossible for dirt, etc., to enter the oil-cup.

Collars.—The bolster bearing is also a very important matter, and consists of special bearings, called **collars,**

securely fixed to the spindle rail. Either long or short collars are used, and these are generally fastened as shown

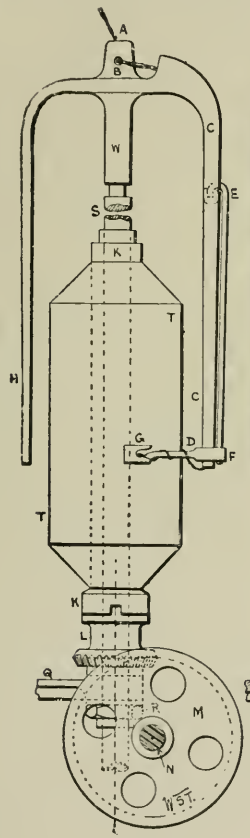


Fig. 69.

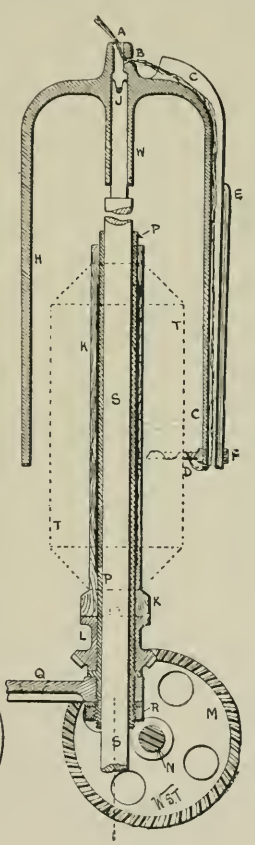


Fig. 70.

in Fig. 70. The lower portion of the collar fits a hole bored in the rail, and, by means of a shoulder, is bedded very truly to a milled facing provided for that purpose.

It is then firmly fastened on its under side by a nut R, and frequently by a set-screw at the side of the snug. A long collar is shown in the drawing, but much difference of opinion prevails as to the merits or demerits of the two kinds. Each, however, has its advantages, those of the short collar, being, of course, obvious. It is made of just sufficient length to serve the purpose for which it is intended, viz. to support the spindle; but when we consider the great length of spindle above the bearing, and also the flyer, which is practically unbalanced throughout the whole

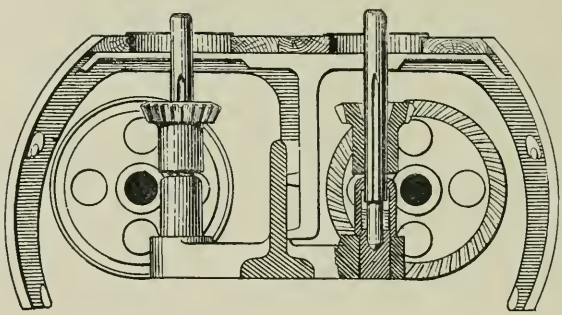


FIG. 71.

of the time it is building the bobbin, it will readily be seen that it is advisable to give more support than is obtained by the short collar, especially for high speed. Practical difficulties, however, used to stand in the way of their use: the correct boring of a long collar was no easy matter, and it was found that, owing to this irregularity, friction was developed, and more power was required to drive the frame. The bearing points were generally at the top and bottom of the collar, the intermediate part being barrelled or recessed out. Modern tools have now overcome these difficulties, and a perfect long collar can easily

be made. The recess is also dispensed with by several makers, as dirt and fly accumulate on the inside and interfere with correct working. The spindle thus bears the whole length of the collar. Another disadvantage of the long collar is the fact that a large bobbin is necessary, owing to the larger hole required to fit over the collar, this, of course, causing extra weight.

Flyer and Presser.—The flyer fits upon a reduced portion of the spindle by means of a socket, a recess being cut across the top, into which drops a pin J, inserted in the boss part of the flyer (Fig. 70). In this way the two parts are made one, so far as revolving together is concerned. The roving is inserted in a hole A in the flyer top, and passed through a small opening B in the side. The mere fact of passing the roving through this last opening gives to the flyer its ability to produce twist, for B is clearly out of the centre of the spindle, and describes a small circle as the flyer revolves. The other end of the roving is held by the roller; every revolution of the spindle naturally gives a twist, and, according to the relative speeds of the flyer and front roller, we get varying degrees of twist—generally expressed as **twists per inch.** The length of the bobbin to be built, and the weak nature of the roving, necessitate that it should be guided on the bobbin at a point much lower than where it emerges from the hole B, and we thus get a long arm, made hollow, down which the roving is passed. From the bottom of this arm it is wound round, and then threaded through the eye of a projecting arm loosely attached to the flyer leg, and from this it is drawn forward by the bobbin. The projecting piece D is termed a **presser**, its function being to give as light pressure to the roving on the bobbin in order to obtain a firmer result. It is specially arranged

to do this, and reference will now be made to the method adopted; but it ought to be first remarked that, in order to balance the arm C, another arm H is made on the opposite side, of such dimensions that its weight balances that of the hollow arm.

The Presser and its Functions.—The "presser" is composed of two parts—one is the projection called the paddle, or presser, and the other a thick wire rod running up the side of the leg, and centered at E, the two being

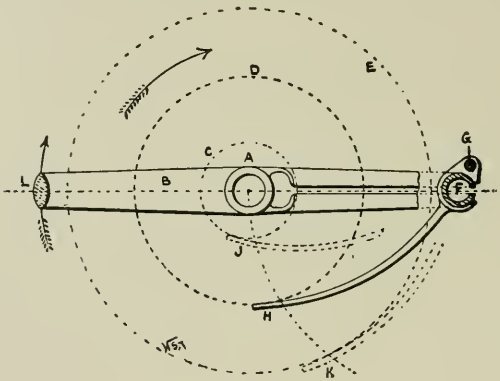


FIG. 72.

connected at F. The paddle D is made to fit loosely over the flyer leg, and as E is capable of swivelling from its centre, which is practically that of the arm C, it is clearly seen that any movement of the wire rod will be transferred to the paddle. To illustrate this further, a plan view of a flyer is given in Fig. 72. G is the rod running up the side of the leg, H is the paddle working round the leg F as a centre; G also, for all practical purposes, works round the same centre. The weight of G is greater than that of the paddle, and, in addition, it revolves at a farther distance

from the centre of the spindle, so that it has a greater tendency to fly away from that centre. It is free to do so, but is guided by its connection to F; the centrifugal force thus tending to move G outwards being resisted by the bobbin, which prevents the other end of the paddle moving inwards. A pressure is consequently set up at H, which causes H to press against the roving on the bobbin, and we therefore get a more solid bobbin.

As made in our machine shops, the flyer is perfectly

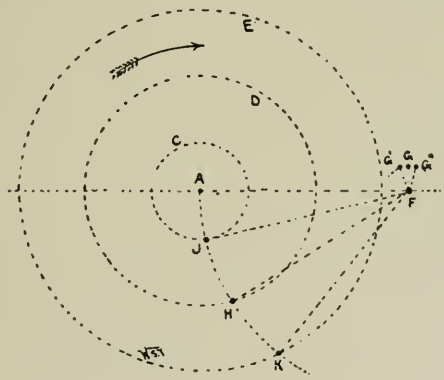


FIG. 73.

balanced when the presser occupies the position shown at H in Fig. 72; but this is the only place where such a condition exists. The presser, being a movable piece that is continually changing its position, disturbs the balance directly it assumes any other position than that shown.

A diagram is given in Fig. 73 from which the foregoing description may be supplemented, and the unbalancing character of the presser explained. C is the bare bobbin, D its middle diameter, and E the full diameter. The flyer leg is marked at F, and the paddle, in its several positions,

at J F, H F, and K F, the respective positions of the wire rod being shown at G^{I}, G, and G^{II}. When the paddle is pressing on the bare bobbin at J, the weight is at G^{II}, at its farthest distance from A. In this position it is exerting its greatest tendency to fly outwards, and, as a consequence, the paddle will press the more firmly at J. As the bobbin is building the increasing layers will move the paddle outwards, this action, of course, bringing G nearer to the centre A, in which position its surface velocity is not so high, and therefore it exerts less force to fly outwards, so that the pressure on the bobbin at K is less than at H or J. It must not be forgotten, also, that the paddle itself has a tendency to fly away from the bobbin owing to centrifugal force, and is only prevented from doing so by the superior weight and the greater distance of G from the centre A. This tendency on the part of the paddle increases as the bobbin fills, so that as the centrifugal force of G decreases, the same force in the paddle increases, and both these result in a diminished pressure of the presser as the bobbin fills. By altering the relative weights of the wire rod G and the paddle, almost any degree of firmness or softness can be obtained on the bobbin.

It will readily be comprehended from the above reasoning that this altering of the centre of gravity of the presser brings a slightly additional weight nearer or farther away from the centre, and so disturbs the balance of the flyer. With a single pressure this is inevitable, and as nothing very serious results from it, it is almost ignored. Some time ago, however, an attempt was made to obtain a perfect balance throughout the building of the bobbin by the introduction of double pressers, one on each arm, but they are never made at present.

The different surface velocities of the bobbin and the

flyer cause a rubbing action between the presser and the roving on the bobbin, and everything is done by careful workmanship to neutralise the evil effects that may arise from this cause. In a double flyer this evil would be twofold.

Flyer Leg.—The slot in the flyer leg is usually made straight, as shown at A in Fig. 74, but for high speeds and fine rovings there is an advantage in making it with what is called "winding" in it—that is, with a slightly curved form, as at B. This prevents the centrifugal force sending the roving through the slot. A flyer, it must be said, is one of the most highly finished appliances in cotton machinery, and a very large number of operations have to be gone through before a finished article is obtained. It must be perfectly smooth all over, and made of the finest material, to prevent accumulations of fly, etc., which would be fatal to good yarn.

FIG. 74.

Previous sketches will convey some idea of how the driving of the spindles and bobbins is performed, but a complete view is given in the following sketch (Fig. 75). A is the bobbin wheel on the driving shaft (but not driven direct from it); the two rows of bobbins are connected by a pair of wheels C and D, which necessitate the arrangement of the bevels as shown at E F and H G; the spindles are driven direct from the driving shaft through the wheel N, which is fixed to it, the necessary gearing being shown in the latter case simply by dotted lines.

A description has been given of the flyer and the bobbin, with their driving arrangements, sufficient to enable the

following explanation to be made of the method adopted in placing the roving upon the wooden cylinder that forms the foundation of the bobbin. There is always a real difficulty experienced by students in comprehending the proper meaning of the terms **bobbin leading** and **flyer**

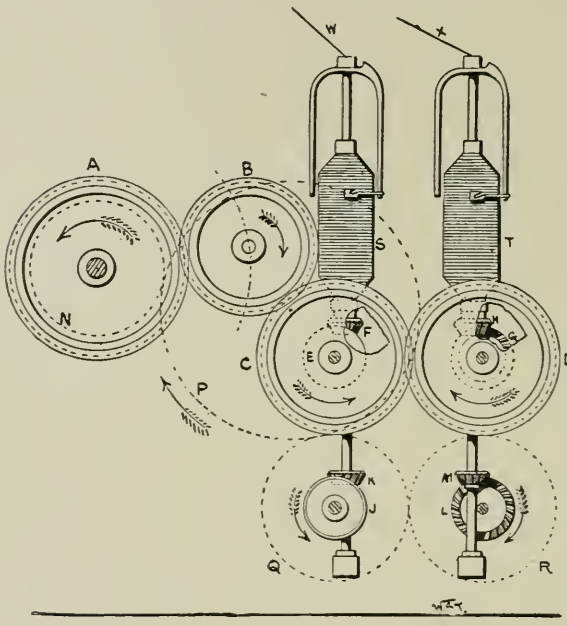


FIG. 75

leading; and although a general statement of their purpose can easily be made, and, perhaps, as readily understood, yet the analysis of their operations is not so satisfactorily apprehended. An attempt will therefore now be made to present the subject in as clear a light as possible, and the diagrams accompanying the description will materially help towards making it intelligible.

Principle of Winding.—As already explained, the roving comes from the rollers at a continuous and regular rate, which is dependent upon their surface speed or revolution. The problem to be solved, therefore, is how to place this roving upon the bobbin at exactly the same rate as it is delivered from the rollers. Two methods have been adopted: one, in which the flyer wraps the roving upon the bobbin; and the other, in which the bobbin winds it round itself. These give rise to the two terms mentioned above, but before indicating the present practice, an examination will be made of the principles upon which "winding," as it is called, depends.

A simple illustration will be given in the first instance on the effect of the relative velocities of two points;—it is upon this feature that the winding has its basis. In Fig. 76 (top left-hand corner), A and B represent two points, connected together by some material that can be "paid out" if the points separate. If these points are caused to move in the direction of the arrows, at equal velocities, they will arrive at C and D without altering their relative positions, so that the material connecting them has not been influenced in any way. If, however, only one point moves, as at E, the material must be paid out in order to keep the points connected, the amount being denoted by the line F, G. This length, of course, would be doubled if the point F, instead of being fixed, were caused to move in the opposite direction. A modification of this case is shown in H and I, where H moves to J at the same time as I moves to K, only half the distance separating them, which denotes the amount paid out; it would give the same result if the relative movements of H and I were reversed.

Another illustration, approaching more nearly to the conditions of the special case of the fly-frame, is represented

by the first five diagrams, and shows the effect when a circular movement is made by the points instead of a horizontal one, as in the preceding case: A and B are two points, connected as before with material capable of being

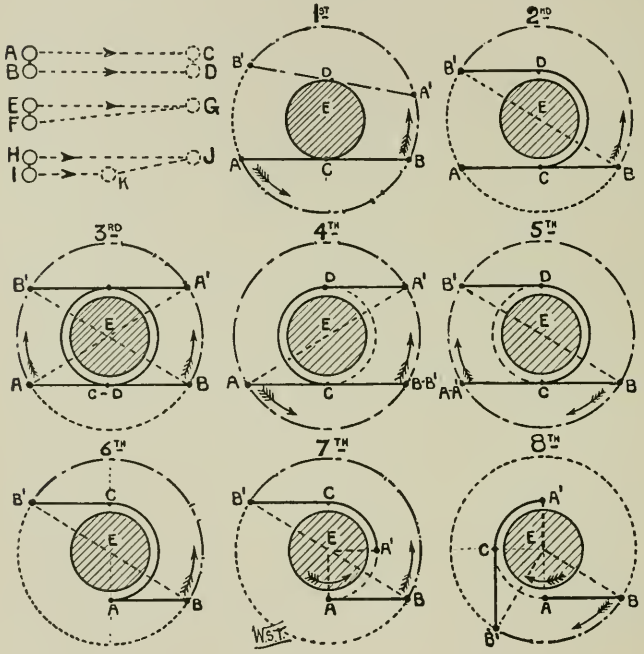


FIG. 76.

paid out by one or the other or both—but for simplicity say B. Each point moves round the centre, and we require to know the effect of the respective velocities of A and B upon the material as they move round the centre. In the first case they move at equal velocities in the same direction, so that on reaching the position A^1 B^1 no change

in the line joining them has taken place; it remains exactly the same length as before. In the second diagram, A remains fixed while B moves, and it is readily seen that B no sooner begins to move than the material must be given up in order to maintain its tension, so that when B arrives at B^1 the amount of this material is represented by the semicircle C D. By causing A to move in the direction opposite to B (as in case 3), half a revolution of each would cause a complete turn of the material to be made round E, half of which would be wrapped round by A, and the other half by B.

In Diagrams 4 and 5 a modication of the first two diagrams is given, both points, A and B, being allowed to move in the same direction, but at different velocities. By reference to Diagram 4, B is supposed to make a complete revolution at the same time as A makes half a revolution to A^1; this has the result of winding on half a revolution of the material on E. It will be seen that B's movement would give a complete turn; but since A moves in the same direction, half of it only will be laid on the centre E. Diagram 5 represents the reverse of this, though producing the same results: A is made to go through one revolution during the time that B makes half a revolution. The peculiarity to notice here is the direction of motion compared with that shown in Diagram 4: this is a necessity if the tension of the material between the two points is to be maintained, for if the direction were reversed in No. 5, the superior speed of A over B would instantly cause the material to go slack, and the first condition of winding would be destroyed. There is one way of keeping the same direction of rotation in the two cases, and that is by reversing the positions of A and B. This would make No. 5 case almost similar then to No. 4, with the exception

that the material is given up from the opposite side of the circle that forms the path of the movement of the points.

From this illustration a step farther may be taken, of a more practical character, and directly connected with the actual effect of winding. We have seen from the examples given that a material can be wound round a centre bobbin when two points through which it passes are revolving at different speeds. By giving a diagrammatic view of the conditions existing in the fly-frame this may be fully exemplified and made obvious. For this purpose the 6th, 7th, and 8th diagrams have been prepared, the reference letters corresponding in each case: E is the centre bobbin upon which the roving is wound; B is the flyer through which the roving passes to the bobbin; its path is shown by the dotted outer circle; A is the point where the roving is laid on the bobbin.

In Diagram 6 it is assumed that the bobbin is stationary and the flyer B revolving. When B has gone through half a revolution it will naturally have wrapped upon the bobbin a length of roving equal to half of the circumference of E, as shown by the line A C. Now this is a perfectly natural way of placing the roving upon a bobbin as far as a single layer is concerned; but practical considerations in respect of placing a number of layers upon it necessitate a modification of this case, in which the bobbin itself is given a motion, but in its degree varying from that of the flyer. Two cases are given: one (No. 7) in which the flyer moves more quickly than the bobbin, technically called "flyer leading"; and the other case (No. 8) in which the speed of the bobbin is much the quicker—from which we get the term "bobbin leading."

On reference to Diagram 7, if the flyer B revolves through half a circle to B^1 while the point A on the bobbin

only goes a quarter of a revolution to A^1, it is obvious that the two points A and B will separate to the extent of the quarter of the circle A^1 C; in other words, since the tension remains constant this length of roving has been drawn through the flyer leg B and wound upon the bobbin. Now take the case of diagram 8: here A and B occupy the same position as in No. 7, but the bobbin is assumed to go half a revolution in the same time as the flyer B goes a quarter of a turn to B^1. The first thing to notice is the direction of movement: it is clearly impossible, as they are at present arranged, for them to move in any other direction; otherwise, since A moves quicker than B, the roving would go slack between the two points. It is therefore necessary in bobbin-leading, as compared with flyer-leading, either to change the direction of driving or reverse the position of the presser of the flyer which corresponds to the line A B.

In respect of the winding, it will be seen that the point A moves half a turn to A^1; at the same time the flyer B has gone a quarter of a turn to B^1, which clearly causes a separation to take place between the two points A and B to the extent of the portion of the circle A^1 C. This length has been drawn from the flyer owing to the superior speed of A, and for the same reason it winds it upon itself, as shown. At the present time all fly-frames are made with **bobbin-leading**, as this system is found to possess superior practical advantages over the **flyer-leading**. The reason for this adoption will be given subsequently when dealing with the problem of building the bobbin.

Flyer leading.—If the foregoing description has been closely followed it will have prepared the reader for the next step explanatory of the process of building the bobbin. The two diagrams, Figs. 77 and 78, have been prepared in order to elucidate it, and in connection therewith a little

recapitulation will be necessary. Fig. 77 represents the case of the "flyer leading"; in it the flyer B is shown as having moved through half a revolution to B^1 in the same time as the bobbin E has revolved one quarter of a revolution to A^1. This results, as already shown, in the flyer winding on the bobbin a length of roving equal to a quarter the circumference of the bare bobbin, represented by the thick line A^1 C. The relative velocities of the flyer and bobbin will keep the same until the first layer is completed, but when we come to wind the next layer

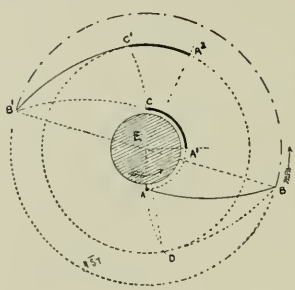


FIG. 77.

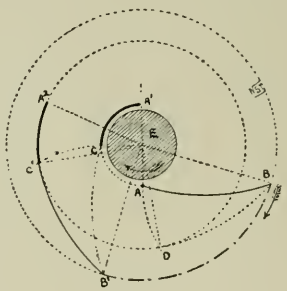


FIG. 78.

upon the first one, it must be done on a larger diameter; —and this fact introduces a new order of conditions, which will now be dealt with, and which brings us face to face with the real problem of winding. As a preliminary, two conditions must be remembered, viz. the flyer revolves at a constant speed, and the roving is delivered regularly from the rollers whatever diameter the bobbin may be. The conclusion to be drawn from this latter fact is, that the bobbin must run at such a speed as to wind on exactly the same amount of roving as is delivered from the front roller, whether it be full or empty. The effect of winding on a larger diameter will now be considered, and in order

to emphasise the matter the difference between the empty and the full bobbin will be taken as an illustration. On the empty bobbin, C A^1, Fig. 77, is wound on during the same time as the flyer B moves through half and the bobbin E through a quarter of a revolution. Now, on the full bobbin, this length C A^1 must be wound on in exactly the same time as on E; the position of the presser (along which the roving travels) has moved from B C to B C^1 (or from B A to B D); C^1 is therefore the point of contact where the roving enters on the full bobbin, and from here to A^2 (shown by a thick line) is represented a length C^1 A^2, equal to C A^1. Whilst the flyer has therefore moved half a revolution, the bobbin must have gone through a much larger angle than a quarter of a revolution, as it did when the bobbin was empty: in other words, it has had to increase its speed from a quarter to almost half a revolution, the angle D E A^2 representing the exact amount. From this it is seen that when the flyer leads, the bobbin, starting at a certain speed when empty, must gradually increase its rate of revolution as it gets larger in diameter.

Bobbin leading.—The case of the "bobbin leading" will now be taken, Fig. 78 being used for reference. As before observed, the bobbin E has the quickest speed, and while it goes through half a revolution, from A to A^1, the flyer moves through a quarter of a turn, from B to B^1, with the result that the empty bobbin winds on itself a length of roving equal to C A^1. As the bobbin fills, the presser will move outwards from A to D, and when the flyer makes its quarter of a revolution it will occupy the position B^1 C^1. From this point a length of roving C^1 A^2 is shown on the full bobbin equal to the same length C A^1 on the empty bobbin. On the empty bobbin it required

half a revolution to wind this length on, but on the full bobbin it will be seen that only a little over quarter of a revolution is required, as shown by the angle D E A^2. This means that as the bobbin fills it must gradually decrease in speed from what it started with as an empty bobbin.

To sum up the questions that have just been discussed: we may say that with the "flyer leading" the flyer revolves quicker than the bobbin, and, as the bobbin increases in diameter, its speed must increase in order to have wound on it the same length as on the smaller diameter. When the "bobbin leads," the bobbin revolves at a quicker speed than the flyer, and as it increases in diameter it must decrease in speed; its direction of revolution is opposite to that when the flyer leads, or else the flyer must be on the opposite hand.

At the present time the "flyer leading" has fallen into disuse. Several reasons are assigned for this; one objection is the increase in speed necessary for the bobbin as it enlarges and gets heavier; another is the fact that through the indirect driving of the bobbin by means of a strap on the cone drums the flyer is caused to start a little earlier than the bobbin, which produces a strain on the roving, and results in frequent breakages. This evil is traceable also to the general gearing, and is said to be the result of more backlash existing in the larger number of wheels used in the driving of the bobbin than in the driving of the flyer. Each may be accredited with its share of the condemnation of this principle, and although the same conditions exist, yet they do not appear as evils when the "bobbin leads," for, instead of the late start of the bobbin resulting in a strain and breakage, the roving is slackened a little; this, however, is quickly taken up in

the course of a revolution or so as the strap and wheels drop into their working positions. A simple illustration will show the necessity for slowing the bobbin as it fills. It is as follows:—Suppose a bobbin one inch in diameter turns once round; in so doing it will wind on itself 3·1416 in. of roving. If it be now enlarged to 3 in. diameter one revolution will wind on 9·4248 in., so that for the larger diameter to wind on the same amount as the smaller one it must make one-third of a revolution. The reason for not giving this example at an earlier stage is obvious: it would not have been consistent with the example of the "flyer leading," in which case we saw that the bobbin must increase in speed as it enlarges; it was therefore considered preferable to explain the matter in the first instance on the general principles applicable to both cases. The above illustration, however, is a very valuable one as enumerating the principle of the example when the bobbin leads, but a warning must be given that such a reduction in speed as is there mentioned never actually occurs in a fly-frame, although a greater difference than 3 to 1 exists between empty and full bobbins.

It must be firmly impressed upon the reader's mind that reduction in speed as the bobbin fills relates only to that portion of its speed which is in "excess" of the speed of the flyer. An example of this may be seen in Fig. 78, where the empty bobbin turns half a revolution while the flyer only turns a quarter. Now the full bobbin is clearly more than twice the size of the empty one, and yet its speed is obviously more than half what it was originally. Such a result is very puzzling to those who rely upon the conclusions drawn from the simple illustration given, without considering its real application. In Fig. 78 the point to notice carefully is that the excess speed of the

empty bobbin over the flyer is represented by the angle C E A^1, shown bordered by the black line, and indicating the amount of roving wound on, when the bobbin is full, and over twice the diameter of the empty bobbin. Its excess speed is shown by the angle C^1 E A^2, which is, as it ought to be, less than half of C E A^1, and is bordered by exactly the same length of an arc as on the smaller circle. It may be added that, no matter how large the bobbin, its speed would never be reduced to one-half, and the excess speed, although gradually reduced, would never be eliminated.

Principle of Winding.—We can now make a closer inquiry into the reduction of speed necessary for winding on the same amount of roving on different diameters of bobbin. Suppose that Q (Fig. 79) represents the bobbin, and that, after a number of revolutions, its excess speed over the flyer has enabled it to wind the roving once round itself, as at A B. Further layers are added, as at C E G, etc., and the question is—What reduction must take place in the excess speed at these points in order to wind on the same length of roving? It is quite unnecessary to give the actual calculation required to obtain it, it is sufficient to point out that since the excess speed is represented by the length wound on, its amount can easily be found for any given diameter. For instance, the outer circle at T was 7 in. diameter in the original drawing, and the smaller circle 1 in. diameter; so that one-seventh of the large circle equals the full circumference of the inner one. This is what is shown in the diagram at T U; at 4 and 5 the circle is 4 in. in diameter, consequently one-fourth of its circumference equals A B, and for the same reason the circle 2, 3, which is 2 in. in diameter, has half its circumference marked off as equal to the circumference

of Q. Any of the other points can be found in the same manner, and this becomes a very simple matter indeed when we recognise the principle underlying the diagram, which may be expressed as follows:—As the diameter of the bobbin increases, its rate of revolution must be reduced

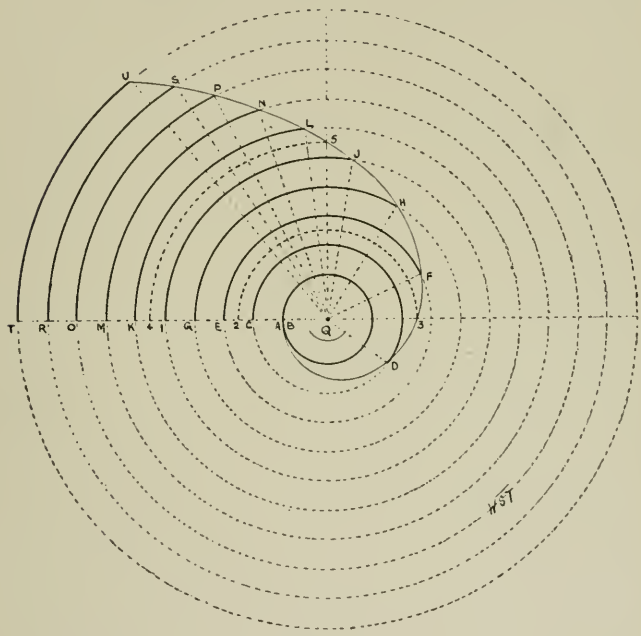


Fig. 79.

in inverse ratio; for, as just shown, twice the diameter requires half the speed, four times the diameter, one-quarter the speed, etc. The diagram (Fig. 79) is constructed in this manner, and the amount of each circle or diameter occupied by a similar length of roving is shown by the thickened line; the ends are joined by a curve,

which accurately defines the limits of the roving, equal to the circumference A B. This curve is a most important factor in designating the values of the varying speeds for the different diameters, and it is evident that its foundation depends on the intersection of the radial lines U Q, S Q, etc., with their respective circles U T, S R, etc. These radial lines form angles with the foundation line T Q, while the length of the arc is the same in all the circles; the angles enclosed by it vary considerably, and it is their variation that produces the curve. By plotting out this curve, either by taking the angles for our values, or by taking the proportion of the circumference occupied by each arc as our basis, and calling the smaller circle one, we obtain the curve represented in Fig. 80. In this form the curve presents its true characteristics, and it is at once seen to be a hyperbola. In the first place, it was made from the angular values in the following manner: a line, T A, was taken and divided into parts equal to the layers on the bobbin in Fig. 79, perpendicular lines were erected at the points of division, and on them were marked off lengths equal in value to the various angles; A B, for instance, represents 360°, because a full circle at Q contains 360°; again, at T U, this line represents 51° 25′ 43″ as equal to the angle T Q U, and so on with the other lines. In order, however, to adapt it to the other method, the length T A has been made equal to the full diameter, 7 in. At each inch, then, erect a perpendicular, and make the one at A B any convenient length. The length of the others can readily be obtained as follows:—Call A B one, as representing an inch in diameter; each division will then be numbered as two, three, four, etc., up to seven, and will be the corresponding inches from the end of the line A. The increase in diameter will therefore be repre-

sented on the horizontal line, and the decrease in speed on the vertical lines, and these latter will be reciprocal to the former. For instance :—

Diameters are	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.
Speeds will be	1	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{7}$
Represented as	AB	$\frac{1}{2}$AB	$\frac{1}{3}$AB	$\frac{1}{4}$AB	$\frac{1}{5}$AB	$\frac{1}{6}$AB	$\frac{1}{7}$AB

It will be noticed from the above that this relation must always hold good, viz. the diameter multiplied by its speed must always give the same result throughout the building of the bobbin. By carefully measuring the

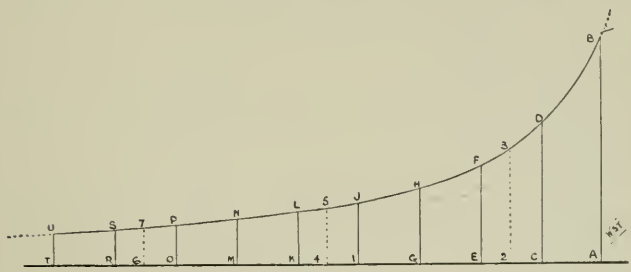


FIG. 80.

diagram (Fig. 80), or making a new one, the following relationship between the speed and diameter will be found to hold good :—

At A=1 in. dia., has its speed A B represented by AB.

At 2=2 in. dia. (twice the dia. of A), has its speed 2 3 represented by $\frac{1}{2}$ A B.

At G=3 in. dia. (three times the dia. of A), has its speed G H represented by $\frac{1}{3}$ A B.

At 4=4 in. dia. (four times the dia. of A), has its speed 4 5 represented by $\frac{1}{4}$ A B.

At M=5 in. dia. (five times the dia. of A), has its speed M N represented by $\frac{1}{5}$ A B.

At 6= 6 in. dia. (six times the dia. of A), has its speed 6 7 represented by $\frac{1}{6}$ A B.

At T=7 in. dia. (seven times the dia. of A), has its speed T U represented by $\frac{1}{7}$ A B.

We may now summarise this explanation as follows:—

In order to wind on the roving, the bobbin must always have a greater speed than the flyer (bobbin leading).

As the bobbin increases in diameter this excess speed must be decreased.

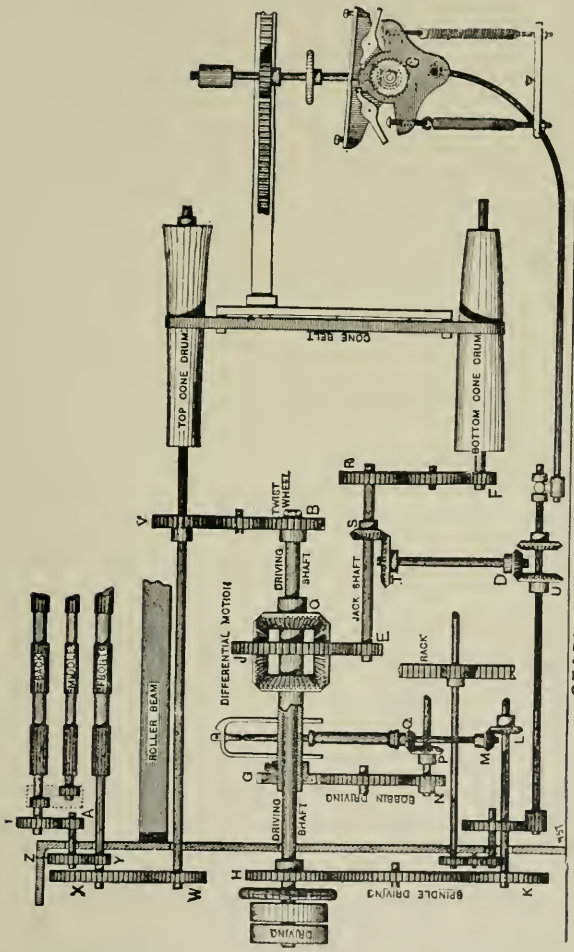
The reduction in the excess speed must be the reciprocal of the increase in diameter: for instance, if the bobbin be made twice the diameter, its excess speed must be reduced to one-half; if the increase in diameter be three times, the excess speed is reduced to one-third, etc.

The curve representing the combination of an increase in diameter with a reciprocal decrease in speed is known as the "hyperbola."

The variation in the speed of the bobbin as it increases in diameter must be consistent with the principles of the above curve.

Driving the Bobbins.—In applying the arguments just concluded to the actual operation of winding, it will be unnecessary to refer to previous methods. At the present time one system is practically universally adopted of effecting the required change in the speed of the bobbin, viz. by the use of cone drums, on the same principle as in the scutcher and opener. On reference to Fig 81 (which exhibits the full gearing of the fly-frame) it will be noticed that the spindles are driven direct from the driving shaft through the wheels H, K, L, and M. It will also be seen that the bobbins are driven direct from the same shaft through the bevel O, which is fixed to the shaft and forms one of an epicyclic train of wheels, called a "differential motion." The wheel G is connected with this, and from here the bobbins are driven through the wheels N, P, and Q. As near an approach as possible is given to the speed of the spindle and bobbin consistent with the function of

the differential motion, and it must be carefully noted



GEARING PLAN OF FLY FRAME.

FIG. 81.

that both, to this extent, are driven direct by positive gearing.

Cone Drums.—The excess speed of the bobbin must now be considered. Cone drums are introduced, one of which is driven from the driving shaft through B and V, the bottom one being connected to the differential motion by the wheels F, R, and E. This has the effect of giving the necessary "additional" movement to this motion (the action of which will be subsequently made the subject for examination), and this excess speed is transferred to the bobbin through the wheels previously mentioned.

The statement was made in some previous remarks that the amount of roving wound on the bobbin represented the excess speed of the bobbin over the flyer, so that if a bobbin starts with a certain excess speed, its reduction must take place inversely to its increase in diameter. If, therefore, the full bobbin be four times the diameter of the empty one (which is about the limit in fly-frames), the excess speed must be reduced to one-quarter. This gives a basis to work upon, and there is no occasion to know the actual number of revolutions of this speed, as it is merely a question of gearing, and need not be taken into account in constructing the cone drums for their special purpose. Let us take for illustration the empty bobbin as being 1 in. in diameter and the full bobbin as 4 in. in diameter. This will mean that the diameter of the cone drums must be arranged to give a reduction of four from one extreme to the other. The diameters suitable for this, which several of our principal machine makers adopt, are : $3\frac{1}{2}$in. for the small end, and 7 in. for the large end of each cone drum. When the strap is on the large end of the top cone and driving the small end of the bottom one, the bare bobbin is winding. As layers are added the strap is moved gradually by a special appliance to the other end, where a small diameter of the top cone drives the large end

of the bottom cone, in which case the largest diameter is winding on the roving.

Formation of Cone Drums.—Two diagrams are given in Figs. 82 and 83 to illustrate the further reasoning and to show its result graphically. In order to reduce the question, at first, to its simplest form, the speed of the bare, middle, and full bobbin will be found, each of which is represented by A, B, and C respectively in Fig. 82; these diameters may be taken as 1 in., $2\frac{1}{2}$ in., and 4 in. The top drum is the driver, and, for simplicity, it is

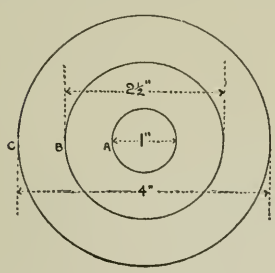


FIG. 82.

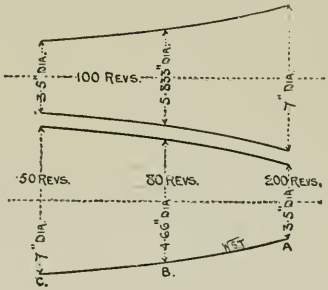


FIG. 83.

assumed to run at a constant speed of 100 revolutions per minute. The extreme diameters E and D will therefore drive the bottom drum diameters G and F at 200 and 50 revolutions per minute respectively. The middle speed is readily found, for, since the diameter is $2\frac{1}{2}$ in., which is $2\frac{1}{2}$ times larger than the empty bobbin, the speed must therefore be the reciprocal of this, which is $1 \div 2\frac{1}{2}$. Or perhaps a more simple way of putting it would be to say that the speed must be the inverse of this increase, $2\frac{1}{2} = \frac{5}{2}$; so its inverse order would make it $\frac{2}{5}$. Now, $\frac{2}{5}$ of 200 (the speed which drives the empty bobbin) = 80 revolutions; consequently the top cone must drive the bottom cone at this

speed when the strap occupies the central position. An important point to notice here is the great reduction in speed that has taken place from the speed of the bare bobbin, and how small this reduction becomes as the bobbin fills. It will serve to impress the reader with the obvious lesson to be learnt from the hyperbolic curve given in Fig. 80, where the reduction in speed is shown, by the quick descent of the curve, to be very rapid for the first layers, and then by the more gradual curvature to diminish at a slower rate as the bobbin gets fuller. It is now merely a question of proportion to get the diameters to suit the speeds, remembering, of course, that the sum of the opposite diameters must be the same, viz. $10\frac{1}{2}$ in.; therefore—

$$\frac{100 \times 10\frac{1}{2}}{180} = 5{\cdot}833 \text{ in. dia. of bottom drum,}$$

and the corresponding diameter for the top drum will be $10{\cdot}5 - 5{\cdot}833 = 4{\cdot}66$ in. If diameters be measured on the diagram equal to these dimensions, and a curve be drawn through their extremities, we obtain the hyperbolic curve that is so characteristic of the cone drum: the top cone becomes depressed or concave in its outline, and the bottom one correspondingly becomes convex. This simple case will enable a more complete example to be the more easily understood, and this we now proceed to give.

The bobbin, as before, is 1 in. in diameter when empty, and 4 in. when full. In order to obtain a sufficient number of points through which to draw the correct form of the curves, the necessary diameters of the drums will be found for every quarter of an inch additional diameter of the bobbin. The lengths of the cone drums are at least thirty inches, and the strap is moved from one end to the other by the transverse motion, step by step, as each

layer is added. Then in the present example the cone drums are divided so as to show the position of the centre of the strap for each diameter of the bobbin. This gives us thirteen position lines for which diameters are required, but, as the two end ones are known, viz. $3\frac{1}{2}$ in. and 7 in., only eleven require calculating. As in the last illustration the top driving cone will be assumed to run at 100 revolutions, in which case the extreme speeds of the bottom cone will be 200 and 50 revolutions, corresponding to the empty and full bobbins respectively.

The following table presents in a very concise form the elements and method of calculating the speeds and diameters :—

A.	B.	C.	D.	E.	F.	G.	H.
in.	in.	in.		Revs.	in.	in.	in.
1	1	1	$1 \times 200 = 200$	100	3·5	7·0	$10\frac{1}{2}$
$1\frac{1}{4}$	$\frac{5}{4}$	$\frac{4}{5}$	$\frac{4}{5} \times 200 = 160$	100	4·038	6·462	$10\frac{1}{2}$
$1\frac{1}{2}$	$\frac{3}{2}$	$\frac{2}{3}$	$\frac{2}{3} \times 200 = 133{\cdot}33$	100	4·5	6·0	$10\frac{1}{2}$
$1\frac{3}{4}$	$\frac{7}{4}$	$\frac{4}{7}$	$\frac{4}{7} \times 200 = 114{\cdot}28$	100	4·9	5·6	$10\frac{1}{2}$
2	2	$\frac{1}{2}$	$\frac{1}{2} \times 200 = 100$	100	5·25	5·25	$10\frac{1}{2}$
$2\frac{1}{4}$	$\frac{9}{4}$	$\frac{4}{9}$	$\frac{4}{9} \times 200 = 88{\cdot}88$	100	5·5	5·0	$10\frac{1}{2}$
$2\frac{1}{2}$	$\frac{5}{2}$	$\frac{2}{5}$	$\frac{2}{5} \times 200 = 80$	100	5·83	4·67	$10\frac{1}{2}$
$2\frac{3}{4}$	$\frac{11}{4}$	$\frac{4}{11}$	$\frac{4}{11} \times 200 = 72{\cdot}72$	100	6·078	4·42	$10\frac{1}{2}$
3	3	$\frac{1}{3}$	$\frac{1}{3} \times 200 = 66{\cdot}66$	100	6·3	4·2	$10\frac{1}{2}$
$3\frac{1}{4}$	$\frac{13}{4}$	$\frac{4}{13}$	$\frac{4}{13} \times 200 = 61{\cdot}5$	100	6·5	4·0	$10\frac{1}{2}$
$3\frac{1}{2}$	$\frac{7}{2}$	$\frac{2}{7}$	$\frac{2}{7} \times 200 = 57{\cdot}14$	100	6·68	3·82	$10\frac{1}{2}$
$3\frac{3}{4}$	$\frac{15}{4}$	$\frac{4}{15}$	$\frac{4}{15} \times 200 = 53{\cdot}33$	100	6·84	3·66	$10\frac{1}{2}$
4	4	$\frac{1}{4}$	$\frac{1}{4} \times 200 = 50$	100	7·0	3·5	$10\frac{1}{2}$

A are the actual diameters of the bobbin in inches.

B are the diameters of the bobbin expressed fractionally.

C represent the reciprocals of the figures in column B, and are expressed by reversing the order of the fractions in that column. These fractions represent the speeds in the same way as column B represents the diameters.

D column gives the speeds of the bottom drum as the

various diameters of the bobbin are built up. They are found, as shown, by taking the fractional proportion of 200 revolutions for each diameter, as represented in column C.

E gives the corresponding speed of the top cone drum, which is constant.

F gives the calculated diameters of the bottom cone drum. These are found by a simple proportion, as follows:—If the sum of two opposite speeds equal the sum of two opposite diameters corresponding to them, what diameter will equal either of the two speeds which make up the sum? Example (for 1 in. diameter):—

$$\frac{\text{Top speed} \times \text{sum of the dia.'s}}{\text{Top speed} + \text{bottom speed}} = \text{dia. of bottom cone drum.}$$

(1 in. dia. of bobbin) $\quad \frac{100 \times 10\frac{1}{2}}{100+200} = \frac{1050}{300} = 3{\cdot}5$ in. dia.

(2 in. dia. of bobbin) $\quad \frac{100 \times 10\frac{1}{2}}{100+100} = \frac{1050}{200} = 5{\cdot}25$ in. dia.

(3 in. dia. of bobbin) $\quad \frac{100 \times 10\frac{1}{2}}{100+66{\cdot}66} = \frac{1050}{166{\cdot}66} = 6{\cdot}3$ in. dia.

(4 in. dia. of bobbin) $\quad \frac{100 \times 10\frac{1}{2}}{100+50} = \frac{1050}{150} = 7$ in. dia.

G represents the diameters of the top cone drum, which are found by subtracting the diameters of the bottom cone drum from $10\frac{1}{2}$ in.

H is the sum of the opposite diameters. It is scarcely necessary to point out that this is requisite in order to allow the strap to fit regularly throughout the length of the cone drums.

Figs. 84 and 85 embody the above tabulated results. When the strap is at A the empty bobbin is being driven. By the time a quarter of an inch increase in diameter has been made the strap has been moved to B, and so on the full length of the drums, equal divisions representing equal increases in the diameter of the bobbin.

The above method of constructing a pair of cone drums for building the bobbin of the fly-frame is obviously so simple that it is surprising so much difficulty is experienced in explaining it. The whole process may be summarised in a few words: the various diameters of the bobbin are expressed fractionally; these fractions are reversed or inversed, and multiplied into any speed we care to take as representing the empty bobbin; the results give all the speeds from empty to full bobbin. Knowing the speeds, it is a question of simple proportion to calculate the diameters required to produce these speeds; not only

FIG. 84.

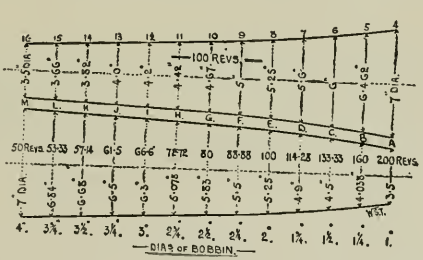


FIG. 85.

is the correct form of the drums given, but the actual hyperbolic character of the curve is denoted, and it is strange that so many mistakes have arisen as to its correct designation.

Whilst appreciating the above method, it is well for the reader to be acquainted with other methods of arriving at the same result, so one or two of them will now be given. In this case, as in the previous one, the extreme diameters of the two cone drums must be decided upon. We will assume the same diameters as before, viz. 3½ in. and 7 in.; and for purposes of reference Fig. 85 may be used. Now divide the length of the cone drums into a

number of divisions in such a way that when they are numbered, the last number is four times the first. (The reason for this is, because four is the proportion between the extremes of the speeds.) In the diagram each division is numbered, commencing at 4, and on up to 16; we thus obtain 13 divisional lines upon which the diameters must be measured. Of two of these we know the dimensions, so 11 remain to be found. Assuming the top cone to be running at 100 revolutions, the following table will show in a convenient form the elements to be used in calculating the diameters and speeds :—

V	Speed of driving cone	=100 revs.
D	Required dia. of driven cone . .	This must be found
M	Greatest speed of driven cone	=200 revs.
P	Required speed of driven cone . .	This must be found
R	Ratio of speeds at the extreme of driven cone .	=4
E	Smallest dia. of bobbin (bare) represented by .	=4
G	Any dia. of bobbin represented by . . .	=4 to 16
S	The sum of the dias. of the cone drum . .	=10½ in.

The speeds of the bottom drum are obtained by inverse simple proportion : for instance, if when the strap is at 4, the driven drum has 200 revolutions, what number of revolutions will it have when the strap is on 5? Inverse proportion gives 160 revolutions. Again, when the strap is on 6, what speed will the bottom drum have? The result is 133·33 revolutions—and so on through the whole numbers from 4 to 16. It will be observed that the inverse proportion is the chief point to be taken into account, and the reason for it is too obvious, after the explanation just given, to require further explanation.

[TABLE

G	P speeds.	D dia.	G	P speeds.	D dia.
4	200	3·5	11	72·72	6·078
5	160	4·038	12	66·6	6·3
6	133·33	4·5	13	61·5	6·5
7	114·28	4.9	14	57·14	6·68
8	100	5·25	15	53·33	6·85
9	88·88	5·5	16	50	7·0
10	80	5·83			

The above gives a tabulated result of the speeds and the diameters deducible from them. Convenient formulæ for both speeds and diameters are :—

$$\frac{ME}{G} = P \text{ (speeds).} \qquad \frac{S}{P+100} = D \text{ (diameters).}$$

Another Method :—The same diagram (Fig. 85) will also serve for illustrating this method. As in the last example, the cones are divided into 13 diameters or division lines, commencing at 4 and finishing at 16. Instead of finding the various speeds of the driven cone as the strap moves forwards, we obtain the "ratio" that must exist between any two opposite diameters. With the end diameters this is a very easy and direct calculation, for at the beginning end the ratio is

$$\frac{3·5}{7} = 0·5$$

and at the finishing end it is—

$$\frac{7}{3·5} = ·2$$

The intermediate ratios, however, cannot be obtained in this way because the diameters are not known; therefore the numbers representing the division lines 4 to 16 must be made use of. It will be noticed that the ratio is a fixed proportion of the numbers which represent the two ends: for instance, $\frac{1}{8}$ of $4 = 0{\cdot}5$, and $\frac{1}{8}$ of $16 = 2$; and in the same way $\frac{1}{8}$ of any of the numbers from 4 to 16 will give the ratio at these points. The formula is as follows:—

$$\text{Ratio of diameters at any point} = \frac{BG}{AE}.$$

The letters referred to are in the following table:—

A	Largest dia. of cone	7 in.
B	Smallest dia. of cone	$3\frac{1}{2}$ in.
C	Required dia. of driving cone (to be found) .	S − D
D	Required dia. of driven cone (to be found) .	S − C
E	Smallest dia. of bobbin, represented by . .	4
F	Largest dia. of bobbin, represented by . .	16
G	Any dia. of bobbin, represented by the numbers	4 to 16
R	Ratio of dia. of cones of any given point .	$= \frac{BG}{AE}$
S	Sum of any two opposite dias. . . .	$= 10\frac{1}{2}$ in.

The formula for the ratio works out as follows:—

$$R = \frac{BG}{AE} = \frac{3{\cdot}5\ G}{7 \times 4} = \frac{3{\cdot}5\ G}{28} = 0{\cdot}125\ G.$$

If this be worked out for each number, 4 to 16, the column R in the accompanying table will be obtained. It is now an easy matter to get the speeds from the ratio, and it is needless to do more than present the method by a formula:—

$$\text{The diameters of bottom drum} = \frac{SR}{R+1}.$$

From this we obtain the column D in the table, and

on comparison with the previous table it will be found that the same diameters are obtained in each case.

G.	$R=\frac{1}{8}$ G.	$D=\frac{SR}{R+1}$.
4	0·500	3·5
5	0·625	4·038
6	0·750	4·5
7	0·875	4·9
8	1·000	5·25
9	1·125	5·56
10	1·250	5·83
11	1·375	6·078
12	1·500	6·30
13	1·625	6·50
14	1·750	6·68
15	1·875	6·84
16	2·000	7·00

It will be seen that the principle in the above method depends upon the important fact that the ratio of the corresponding diameters on each cone drum increases in exactly the same proportion as the diameter. To those readers who have carefully followed out the reasoning employed in the foregoing examples, there will be nothing difficult in understanding the statement just made; indeed it is a natural deduction from the statement that the speed of the bobbins is inversely proportionate to their diameters. The following will make this clear; the speed of the bobbin depends directly upon the speed of the cone drums, so that the speed of the cone drums must vary inversely as the diameter of the bobbin; but the ratio of the diameters of the cone drums are inversely proportionate to the speeds which they give—for instance, a 3-in. pulley driven by a 6-in. pulley is one-half the size, but its speed is doubled—therefore the ratios of diameters of the two cone drums must increase in the same proportion as the diameters of the bobbin increase.

ANOTHER METHOD.—A modification of the above method can now be given, which depends on finding the ratios of the cone drums from the diameters of the bobbin; but by incorporating the sums of the diameters in the calculation the obtaining of the ratio becomes unnecessary. Still it must not be overlooked that this ratio is the very principle upon which the method is founded. As before—

A	represents	the largest dia. of driving cone drum .	Say 7 in.
B	,,	the smallest dia. of driven cone drum .	,, 3½ ,,
X	,,	any other dia. of driving cone.	
x	,,	,, ,, driven ,,	
D	,,	dia. of empty bobbin	,, 1 ,,
d	,,	any other dia. of bobbin	1 to 4 ,,
S	,,	sums of opposite dias. of cone drums .	10½ ,,

We can now reason as follows:—

As the initial ratio of the driving cone is to the empty bobbin, so will the ratio of any other opposite diameters be to the corresponding diameter of bobbin. Or, to express it in letters—

(1) $$\text{As}\frac{B}{A} : D :: \frac{x}{X} : d.$$

To those unacquainted with algebra, this could easily be worked out by proportion to get the ratio of the opposite diameters of cone drums, with the same results that appear when the above is formed into an equation:—

(2) $$\frac{B}{A} \times d = \frac{x}{X} D \text{ or } \frac{Bd}{A} = \frac{xD}{X}.$$

(3) $$\therefore X = \frac{AxD}{Bd},$$

(4) $$\text{and } x = \frac{BdX}{AD}.$$

But $X + x = S.$

$\therefore X = S - x.$

And $x = S - X.$

By substituting in (3) the value of X we obtain—

$$S - x = \frac{Ax D}{Bd}.$$

$$Bd\,(S - x) = Ax D.$$

$$Bd S - Bd x = Ax D.$$

$$Bd S = Ax D + Bd x.$$

Divide both sides by x: $\dfrac{Bd S}{x} = \dfrac{Ax D + Bd x}{x}.$

$$\frac{Bd S}{x} = AD + Bd.$$

Divide both sides $Bd S$... $\dfrac{1}{x} = \dfrac{AD + Bd}{Bd S}.$

$$\therefore x = \frac{Bd S}{AD + Bd}. \tag{5}$$

In a similar manner, by substituting the value of x in (4), it can be shown that—

$$X = \frac{ADS}{Bd + AD}. \tag{6}$$

By substituting figures for the above formulæ we can readily obtain diameters of the cone drums corresponding to any required diameter of bobbin. For example, when the bobbin is 2 in. in diameter—

$$\therefore x = \frac{3\frac{1}{2} \times 2 \times 10\frac{1}{2}}{7 \times 1 + 3\frac{1}{2} \times 2} = 5{\cdot}25 \text{ in.}$$

$$\text{and } X = 10\tfrac{1}{2} - 5{\cdot}25 = 5{\cdot}25 \text{ ,,}$$

Again, when the bobbin is 3 in. in diameter—

$$\therefore x = \frac{3\frac{1}{2} \times 3 \times 10\frac{1}{2}}{7 \times 1 + 3\frac{1}{2} \times 3} = 6{\cdot}3 \text{ in.}$$

$$\text{and } X = 10\tfrac{1}{2} - 6{\cdot}3 = 4{\cdot}2 \text{ ,,}$$

These results will be found to correspond with those given in Fig. 85.

Many efforts have been made to improve on the present method of driving the bottom cone drum, but hitherto without sufficient success to warrant their extensive use. The attempts have chiefly been directed towards dispens-

ing with the strap and connecting the drum by some arrangement of friction driving, either directly or by friction bowls. Innumerable mechanical contrivances have been devised for the purpose, but they have proved of little value except from an experimental point. When the subject of the differential motion is being treated, it will be shown that there was a reasonable necessity for trying to effect some improvement in the driving of the cone drums, but it will also be seen that the real difficulty, caused through constant slippage and breakage of belts existed in the motion itself, and, consequently, whilst some people sought for better results in a new form of driving the cones, others looked for the remedy in a new differential arrangement. In the latter case a success has been gained, and the faults previously complained of are now practically eliminated.

The Differential Motion.—In Fig. 81 a gearing view of the fly-frame was given, from which could be traced the whole of the driving. It was especially given to show the driving of the bobbin and the spindles, and in the accompanying remarks it was pointed out that the bobbins as well as the spindles are both driven positively from the driving shaft. This positive system of driving the bobbins must be connected in some way with the varying excess speed given to them through the cone drums, and the problem of how to obtain a combination of two speeds has been solved by introducing into an ordinary train of wheels other wheels on movable centres. An arrangement of this kind is called in mechanics an epicyclic train of wheels; but in the phraseology of cotton spinning it is known as a differential motion. The principle underlying an epicyclic train of wheels is so important that it will be useful to make a few remarks on the elementary part of the subject

before describing the differential motion itself. With this object in view a series of sketches have been prepared that will now be described and the principle of the actions which they illustrate will be explained.

In Fig. 86 a diagram is given showing the simplest form of an epicyclic train of wheels. It consists of two

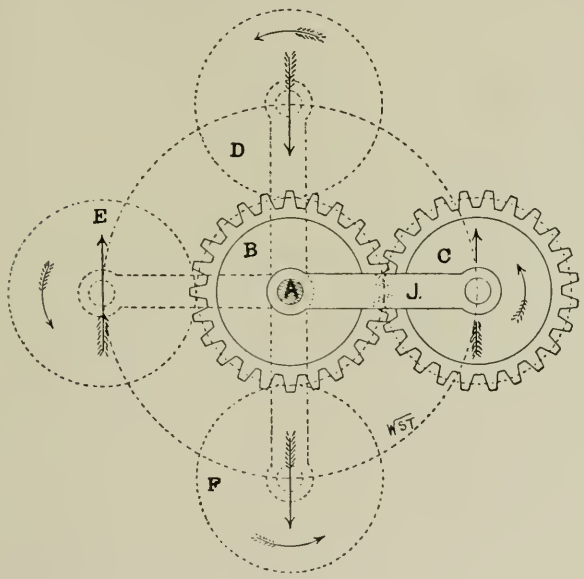


FIG. 86.

wheels, B and C, in gear, and, for convenience, they are made with an equal number of teeth in each. The wheel B is carried on a fixed centre A, while C is carried by a link or arm J, which is capable of turning round the centre A. Under ordinary conditions the two wheels would revolve at equal speeds if they had fixed centres, but by carrying one of them on a centre that can be moved, a new

set of conditions is introduced, and these we will proceed to analyse.

In the first place, suppose the wheel B is fixed so that it cannot revolve. If the arm J is now moved through a complete circle round the centre A, it will carry the wheel C with it. The teeth of C will therefore be in gear with the teeth B during the whole revolution, and, as a consequence, C will be compelled to revolve on its own centre. On examination it will be found to have made two revolutions during the time the arm J has made one; at first sight this result is puzzling and it is not very easily understood. The reader naturally reasons that since C cannot possibly gear with more teeth than are contained by B, and as C has exactly the same number of teeth, therefore C ought only to turn once whilst travelling round B. This reasoning, however, leaves out the important consideration that the mere fact of carrying C round the centre A gives it a revolution of its own, quite independent of its connection with the wheel B; and this revolution must be added to that obtained through the wheels B and C being in gear. This is the reason why we obtain two revolutions of C for one of the arm.

The independent revolution of C is one that students find very difficult to understand. They readily follow the reasoning which shows that C must revolve once through its being in gear with B, but the additional revolution is not so easily understood, and therefore an attempt will be made to explain it as clearly as possible.

In the diagram (Fig. 87) the wheel C is shown, carried by the link J, which is capable of turning round the centre A. The wheel is marked with an arrow, so that any change in its direction can be noted. As the arm carries it bodily in a circle round A, its position in each quarter of

the circle is shown; and it is seen that, when at D, the arrow points in a direction at right angles to its original position, whilst at E it points in an opposite direction to the position at C. The wheel must therefore have made half a revolution in going from C to D, for it is impossible to conceive of its turning upside down without revolving round its axis to do so. In the same way, when passing

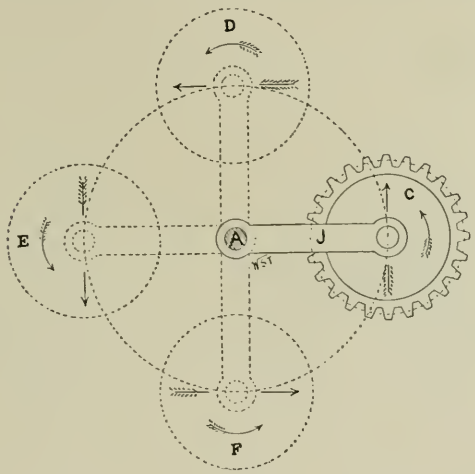


Fig. 87.

from E to C, the arrow resumes its first position, and has thus completed a full revolution. It is this revolution, which has been obtained independent of any gearing, that must be added to whatever revolutions are given to it through its connections with the centre or other wheels. To show by an example that this explanation is correct and can be confirmed, a diagram is given in Fig. 88. The centre wheel B is loose on the centre A, and as the arm J is revolved, the wheel C will turn on its axis and assume

the positions at D, E, and F; and it will be noticed that in doing this it will also cause the wheel B to revolve to the extent that one revolution of the arm will give one revolution to B. A further confirmation that C in Fig. 86 turns twice in being carried round the centre A can be obtained by a consideration of Figs. 89 and 90. In Fig. 89 a side

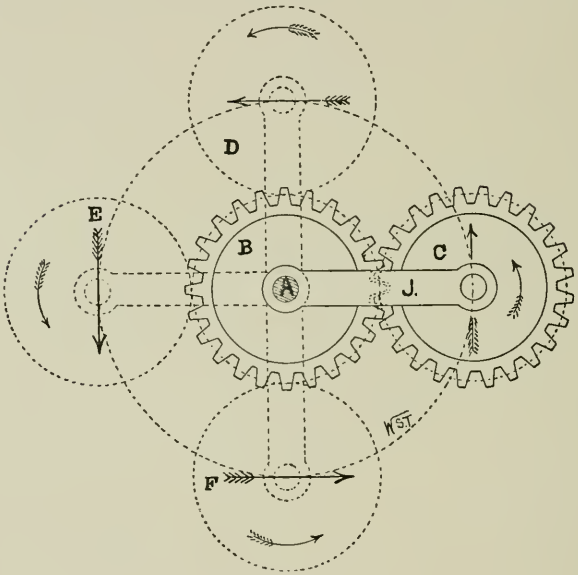


FIG. 88.

view of the wheels is shown: O is fixed on A, so that it cannot revolve; the wheels B and D are carried by the link J, centred at A; B gears into the fixed wheel O, whilst D gears with a wheel C working loosely on the shaft A. If the link J is now turned through a complete circle, it will carry the wheels B and D along with it. B, as we have said, will turn twice, and as it is on the same

centre as D, this wheel will naturally revolve twice. Since D is in gear with C, it is quite clear that C will also obtain two revolutions, so that for one revolution of the wheel B round the centre A, the wheel C can be made to revolve at double the speed. This fact is taken advantage of in many cases, one of which occurs in the well-known wrap reel of our cotton mills; but instead of pinions being used an adaptation is made with bevel wheels, as shown in Fig. 90. As in the previous case, O is fixed on the shaft A, B is geared into it, and also into another bevel C, working

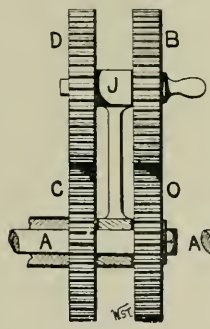


FIG. 89.

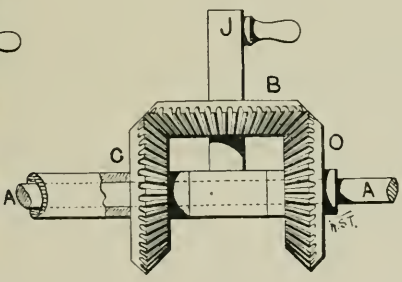


FIG. 90.

loosely on the fixed shaft A. If B, which is capable of being moved bodily round the centre A by means of J, is now revolved round A, the two revolutions it will receive (one because of its being in gear with the dead wheel O, and the other because of its turning round A) are transferred to C, and so we find that one revolution of the handle J produces two revolutions of the wheel C.

So far we have confined ourselves to the consideration of all the wheels being equal; but it is not difficult to see that they may be unequal to each other in any degree that may be found convenient, without altering anything that

has just been explained. For instance, in Fig. 86 B may contain 65 teeth and C 24 teeth; then, if B is fixed and the arm J revolved, C will revolve $\frac{65}{24}$ times by reason of its gearing with B, and once through its revolution round the centre A, so that its total turns will be

$$\tfrac{65}{24} + 1 = 1\tfrac{65}{24} \text{ revolutions}$$

and so on with whatever wheels are used. It ought also to be pointed out that any number of wheels can be geared together and carried by the arm J, and these can be either mere carriers or compounded. If carriers they do not affect any part of the calculations any more than they would in an ordinary train of wheels, but they do affect the direction of revolution, and if the train consists of an odd number of wheels, such as 3, 5, 7, etc., the direction of revolution will be opposite to that obtained when an even number of wheels is used, as 2, 4, 6, etc. Another feature in connection with this motion that must be clearly understood is what is called "relative" motion; that is, the speed of one part of the epicyclic train compared with any other portion. For instance, although the wheel B in Fig. 86 may be fixed, and, therefore, can have no "absolute" motion, it may still have a "relative" motion compared with the arm J, and this relative motion will necessarily be opposite to that of the arm, just in the same way as the impression is given to a person in a moving train that stationary objects passed on the way are apparently moving in the opposite direction; in reality they are fixed, but "relatively" to the train they are moving. The amount of this relative motion can be readily obtained by subtracting the speed of the train from the speed of the object. In the case of a fixed object the result is that it appears to move at the same speed in the opposite direction; if the

object itself moves, the result will vary according to its speed, but the means of obtaining it is always the same, viz. by subtracting the speed of the train from that of the object. This illustration is given because it is familiar to every one, and it applies equally well to the epicyclic train of wheels. This reasoning therefore enables it to be said that the "relative" speed of the centre wheel equals the speed of itself minus the speed of the arm; and the "relative" speed of C (or the last wheel of the train, whatever it may be) equals the speed of itself minus the speed of the arm. This can be expressed much better if letters are used instead of words, and for the convenience of students who have Goodeve's *Elements of Mechanism*, the same reference letters will be used as are there employed for explaining the same subject.

Whilst the arm J makes a revolutions,
let the first wheel B make m revolutions,
and the last wheel C make n revolutions;
also let e be the value of the train wheels.

The value of a train of wheels is found by dividing the speed of the last wheel by the speed of the first wheel.

The above reasoning gives the "relative" speed of—

$$B = m - a,$$

and the relative speed of—

$$C = n - a;$$

therefore the value of the train is—

$$e = \frac{n - a}{m - a}.$$

This gives an equation from which can be obtained any of the elements that may be unknown, provided the others are given; and it will suggest itself to the reader that

three principal methods of arranging the system can be made. For instance :

(1) The wheel B can be fixed, in which case it has no absolute motion ; and therefore $m = o$.

$$\text{Therefore } e = \frac{n - a}{m - a},$$

$$e = \frac{n - a}{-a},$$

$$-ae = \frac{(n - a) - a}{-a},$$

$$-ae = n - a.$$

$$\text{Therefore } e = -\frac{n}{a} + 1,$$

$$\text{and } e - 1 = -\frac{n}{a},$$

$$\frac{n}{a} = 1 - e.$$

$$\text{Therefore } n = a(1 - e),$$

$$\text{and } a = \frac{n}{1 - e}.$$

Or (2) the wheel C can be fixed, in which case $n = o$.

$$\text{Therefore } e = \frac{n - a}{m - a},$$

$$e = \frac{-a}{m - a},$$

$$e(m - a) = -a,$$

$$m - a = -\frac{a}{e},$$

$$m = a - \frac{a}{e}.$$

$$\text{Therefore } m = a\left(1 - \frac{1}{e}\right),$$

$$\text{and } a = \frac{m}{1 - \frac{1}{e}},$$

$$\text{Therefore } a = \frac{me}{e - 1}.$$

Or, again (3), both the arm and the wheels are free to move—

$$\text{Then } e = \frac{n-a}{m-a},$$
$$e(m-a) = n-a,$$
$$e\,m - e\,a = n-a,$$
$$e\,m - e\,a + a = n,$$
$$e\,m - a(e-1) = n.$$
$$\text{Therefore } n = e\,m + a(1-e).$$

This latter case is the one to which most interest will be attracted, as it bears directly upon the actual conditions of the differential motion, and the reader will see that it allows for the driving of the wheels or arm independently of each other. In working out numerical examples of the cases just given it is as well to bear in mind that the value of e will be positive when the train is composed of an odd number of wheels, and negative when an even number of wheels are used. To take an example from Fig. 86. Suppose B = 65 teeth and C = 24 teeth, and the arm revolves 12 times a minute, how many revolutions will C make? From our first case

$$n = a(1-e)$$
$$\text{and } e = -\frac{65}{24}$$ The *minus* sign because there are two wheels in the train.
$$\therefore\ n = 12\left(1 + \frac{65}{24}\right)$$
$$n = 44\tfrac{1}{2} \text{ revolutions.}$$

An example can also be taken from Fig. 90. Here O and C are equal, and it is immaterial what the size of B is. The value of the train e is therefore 1, and as C revolves in the opposite direction to O (which corresponds to the effect produced by an even number of spur wheels), its value becomes –1.

$$n = a(1-e),$$
$$\text{and } e = -1.$$
$$\text{Therefore } n = a(1-(-1),$$
$$n = a(1+1),$$
$$n = 2a.$$

C is thus shown to revolve twice as quickly as the arm J. This result can also be obtained in another way, which is perhaps more suitable for our present purpose. It has already been shown that

$$e = \frac{n-a}{m-a}.$$

Also in Fig. 162 $e = -1$.

Therefore $\frac{n-a}{m-a} = -1$.

Therefore $n - a = a - m$,

and $n + m = 2a$,

which shows that the wheel C revolves twice whilst the arm turns once.

We will now proceed to describe how advantage has been taken of the foregoing principles in producing the differential motion of fly-frames. It is part of the subject that must be thoroughly studied if the students desire to obtain a proper knowledge of it, and for this reason it will be presented in such a way that the reasoning can be readily followed.

In Fig. 91 a drawing is given showing an enlarged view of the differential motion seen in Fig. 81. Only sufficient of the gearing is now represented to serve our present purpose. The first thing to notice on comparing it with Fig. 90 is the method of carrying the wheel B. Here it will be observed the arm J is dispensed with, in its place a spur wheel J being used, and upon its face is fixed an arrangement for supporting the bevel wheel B, at the same time allowing of its free revolution. A is the driving shaft, upon which is fixed the bevel O, and on the opposite end is fixed a wheel H, from which the spindles are driven. The spindles are thus driven direct from the driving shaft A. Referring to the bevel O, we notice that it drives the bevel C through B, and on the elongated boss of C (which

is loose upon the shaft A) is fixed a wheel G, from which the bobbins are driven. The bobbins are therefore driven direct from the driving shaft, and during the whole building of the bobbins the motion received from the cone drums is only a slight proportion of the motion they receive direct.

By mounting the bevel B upon J we are enabled to give an independent motion to what corresponds to the arm in Fig. 65, and it is through this wheel J that the cone

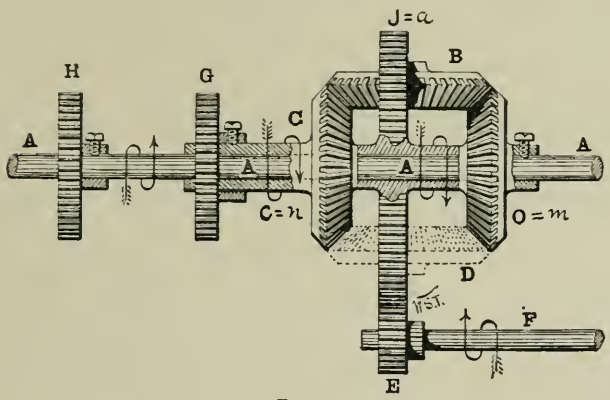


FIG. 91.

drums transmit to the bobbins the excess speed necessary for winding. The connection of gearing for this purpose is clearly shown in Fig. 81, only the shaft F and the wheel E being reproduced in Fig. 91. We are now in a position to analyse the motion. In the first place, the bevel C will revolve at exactly the same speed as O, on condition that the wheel J is held stationary; but its direction will be opposite to that of the shaft A. Now the only way to vary the speed of C (through which the bobbins are driven) is to cause B to be moved round

the shaft A, and this is done by causing J to revolve, which carries B round with it. According to the direction and speed of J it is possible to increase or decrease the speed of C, and as this is the point round which the whole interest centres, we propose to examine the subject carefully, and will commence by assuming that J is revolved in the same direction as O.

(1) Suppose J has the same number of revolutions as O, and in the same direction, it is easy to see that B will be carried round with its teeth locked in O, and therefore it cannot cause C to revolve by its own axial rotation, but simply carries it round at the same speed as J and O; consequently O, J, and C have the same rate of revolution, and all in the same direction. A reference to the formulæ $n+m=2a$ would show this to be the result; for, since $a=m$, we have

$$n+m=2m.$$

Therefore $n=m$,

which proves C to have the same speed as O.

(2) Suppose J to be fixed, O will then drive C at a speed equal to itself, but in the opposite direction: or by using the formulæ, $a=0$ ($m=1$ in all these formulæ)—

$$\begin{aligned} n+m&=2a,\\ n&=2a-m,\\ n&=0-1,\\ n&=-1. \end{aligned}$$

C is thus shown to revolve at an "equal" speed to O, but, as the minus sign denotes, it is in the "opposite" direction. This is therefore an extreme case when J is stationary. We shall now notice the change that takes place as J is revolved in the same direction as O.

(3) Suppose J revolves $\frac{1}{4}$ the speed of O, then—

$$n = 2a - m,$$
$$n = 2 \times \tfrac{1}{4} - 1,$$
$$n = \tfrac{1}{2} - 1,$$
$$n = -\tfrac{1}{2}.$$

Therefore C revolves at "half" the speed of O and in the "opposite" direction.

(4) Suppose J revolves $\frac{1}{2}$ the speed of O, then—

$$n = 2a - m,$$
$$n = 2 \times \tfrac{1}{2} - 1,$$
$$n = 1 - 1,$$
$$n = 0.$$

The speed of C is therefore reduced to nothing when the speed of J equals half the speed of O.

This result represents another extreme, or rather, it might be termed a zero point, for, as we shall see, the speed of J when still further increased causes an increased velocity of C. For instance—

(5) Suppose J revolves at $\frac{3}{4}$ the speed of O, then—

$$n = 2a - m,$$
$$n = 2 \times \tfrac{3}{4} - 1,$$
$$n = 1\tfrac{1}{2} - 1,$$
$$n = \tfrac{1}{2}.$$

So that C now revolves at "half" the speed of O, but in the "same" direction.

(6) Suppose J revolves at the same speed as O, then—

$$n = 2a - m,$$
$$n = 2 - 1,$$
$$n = 1.$$

This is simply the first case repeated, and shows C to revolve at the same speed as O, and in the "same" direction.

It will be observed from these two last cases that any increase in the speed of J, above half the speed of O, causes

an increase in the velocity of C, and it also causes C to revolve in the same direction as the shaft A; but it will be noticed that J requires a high speed, and although it is compensated for somewhat by C running in the same direction as the shaft, which of course minimises friction, its high speed, and the fact that with the flyer leading its speed must be still further increased as the bobbin is filled, result in the adoption of the present method of driving J in the "opposite" direction to O. A similar course will now be followed to show the result of this action on the speed of C. Of course when J is stationary, we get the same effect as was given in case (2).

(7) Suppose J revolves at $\frac{1}{4}$ the speed of O, then—

$$n = -2a - m,$$
$$n = -\tfrac{1}{2} - 1,$$
$$n = -1\tfrac{1}{2}.$$

C thus revolves at $1\frac{1}{2}$ times the speed of O, but in the "opposite" direction. It must be understood, as already explained, that the speed of J becomes a minus quantity when it revolves in the opposite direction to O, and this is the reason for prefixing the minus sign to $2a$.

(8) Suppose J revolves at $\frac{1}{2}$ the speed of O, then—

$$n = -2a - m,$$
$$n = -1 - 1,$$
$$n = -2.$$

The speed of C is shown to be doubled, but the direction remains opposite to O.

(9) Suppose J revolves at the same speed as O, then—

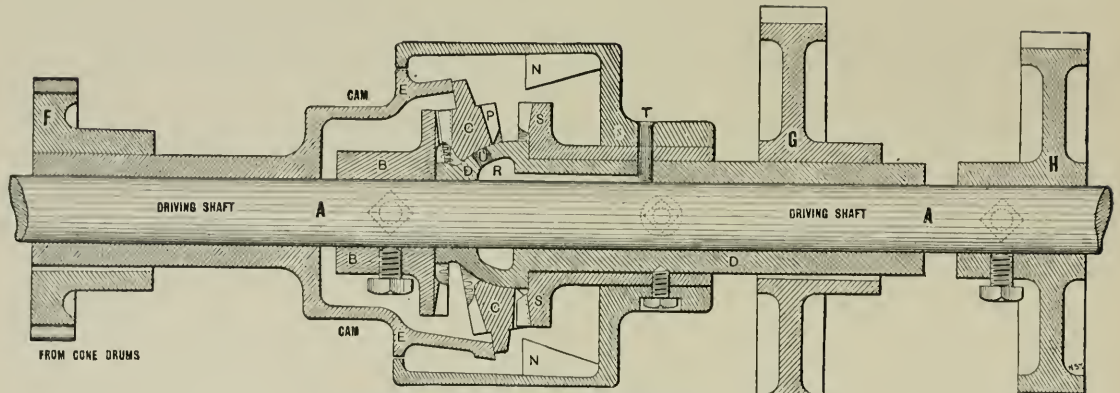
$$n = -2a - m,$$
$$n = -2 - 1,$$
$$n = -3.$$

This result shows a still further increase in the speed of C, but the direction is still opposite to O.

These three illustrations will exhibit the advantages of this method of driving J. It is manifest that, starting from zero, any increase in the speed of J will cause an increase in the speed of C; and, moreover, a high speed of C can be obtained by a comparatively slow speed of J [compare (3) and (7)]. Given this slow speed, when the bobbin leads, it is reduced as the bobbin fills. Its great disadvantage, however, is that the revolution of C takes place in the "opposite" direction to the shaft A upon which it revolves. Great friction is consequently set up between the two surfaces, and naturally there exists a greater strain upon the gearing and the strap of the cone pulley, which gives rise to considerable wear and tear. The whole motion has to be constantly lubricated and the wheels made perfect in their contact with each other; but in spite of these practical difficulties this form of differential motion remained, with only slight alteration as originally designed by Houldsworth, up to within a few years ago, and is even now largely employed. But several improved and ingenious methods have been devised recently for overcoming chiefly the great fault of the "sun-and-planet" motion, or the "Jack-in-the-box"—names by which it is frequently called, viz. the revolution of C in the opposite direction to the shaft A, and also by using a small number of wheels. The reader will see from the explanation that the wheel D, although it forms part of the motion, and is driven exactly like B, is not really a necessary part of it. The only purpose it serves is to balance B on the opposite side of it; it therefore simply represents its weight, and keeps the arrangement running steadily.

One of the most ingenious methods of overcoming the practical objections to the "sun-and-planet" motion is the

one now presented in Fig. 92 (Howarth and Fallow's patent, made by Dobson and Barlow). As the description proceeds it will be found that the epicyclic system is entirely displaced, and a complete novelty in the way of differential gearing is introduced; it is one of the most important mechanical arrangements that have been given to the world for a considerable time, and is superior in every respect to the motion whose place it has taken. The following is a description:—A is the driving shaft to which the driving pulleys are fixed, on it is fastened the wheel H, through which the spindles are driven; a little farther on to the left is a bevel wheel B, also set screwed to A; this bevel, it will be noticed, gears into another but larger bevel C, which is perfectly free from the shaft, and is simply mounted upon a portion of a ball or spherical bearing D, the long boss of which carries the wheel G, from which the bobbins are driven by suitable gearing. On the boss of D is also fixed a clutch-wheel S, which gears into the teeth P on the back of the bevel C; if the shaft A is now driven, B will carry the bevel C round with it. It will be observed that for all practical purposes they may be considered as clutch-wheels, the same teeth for the time being remaining in contact with each other. The same thing happens between the teeth P and those of S, so that when A is revolved, the wheels B, C, S, the ball bearing D and the wheel G (which is keyed to D) all revolve at the same speed as the shaft A, and all in the same direction. This condition exists when the bobbin is commencing, and therefore no friction whatever is present to cause wear and tear on the motion. As a result the belt of the cone drums is perfectly free from the usual strain to which it is subjected in the older differential arrangement.



SECTION OF PATENT DIFFERENTIAL MOTION

Fig. 92.

We now come to the characteristic feature of the motion. In order to maintain the bevels B and C in contact with each other at the same point, a cam E (which is simply a cylinder cut on the slant) bears against the extended outer edge of the bevel C, and is revolved at exactly the same speed as the shaft. This revolution is produced by keying on the boss of the cam a wheel F, and driving it from the bottom cone; the cam is therefore the only means of transferring the varying motion of the cone drums to the bobbin wheel G, and it is done in the following manner:— As the cam E is gradually slowed by the cone drums, it causes the bevel C to oscillate on its spherical bearing, and at the same time compels it to roll round the bevel B. This rolling action will clearly bring into action fresh teeth of each bevel, and thus their point of gearing will be altered. This, however, would serve no purpose if the two bevels B and C were equal in size, for after a single revolution the same teeth would come into gear again, but in consequence of C being slightly larger ($\frac{1}{9}$ larger) the effect of its rolling round B is to cause the point of contact between the wheels to move backwards. This backward motion, although a relative one, results in a direct loss in the speed of C. (The point can be readily tested by taking two bevels of unequal size and rolling the larger one round the smaller; it will be found that after the larger one has geared into all the teeth of the smaller one, it has a few teeth left that have not been brought into contact with those of the smaller wheel. It has therefore not made a full revolution, in fact we can say that it has lost in speed compared with the smaller bevel.) The same thing occurs in this motion, for, directly the speed of the cam E changes, fresh teeth on the two wheels come into gear, and this means a change in speed of the wheel G

which is driven from C through the wheel S. It will, of course, be understood that it requires a number of revolutions of the cam E to cause a small difference to exist between the speeds of the two bevels B and C, and even when they have their greatest variation it is so little that they may be said to drive, because they are in gear as clutch-wheels.

The function of the teeth P and the wheel S is easily comprehended. They save the purpose of transferring the motion of C to the wheel G, and are not wheels for driving purposes, the only two active wheels being B and C, and these, as we have already remarked, differ so little in speed that the whole motion is almost silent, and it is not difficult to see that very little friction can possibly exist, especially since at the commencement of the bobbin the whole arrangement revolves in the "same direction," and at the "same speed" as the shaft A, and it continues in the same direction whilst the bobbin fills. The excess speed is obtained for the bobbin by making the bobbin wheel G slightly larger than the spindle wheel H. The elimination of the epicyclic principle in this motion frees the strap of the cone drum from the strain, which in the older motion it has to sustain in consequence of having to retard the large sun wheel; this is a distinct advantage.

The calculations connected with this motion are exceedingly simple. The wheel C has 36 and B has 32 teeth, as the cam E causes the wheel C to roll round the wheel B it follows that C will gain or lose speed to the extent of the difference of the number of teeth in each wheel; wheel C will therefore gain or lose $36 - 32 = 4$ teeth, *i.e.* it will gain or lose to the extent of $\frac{1}{9}$ of its motion.

To find the speed of the bobbin wheel G we must subtract the speed of F from the speed of the shaft A,

divide the result by 9 and subtract the quotient from the driving shaft A, the answer gives the speed of G.

As a formula it could be expressed thus—

$$G = A - \tfrac{1}{9}(A - E).$$

Speeds are implied in this formula. The speed of the cam E is calculated from the gearing through the cone drums to F.

The oiling of the motion is very complete; the drawing, Fig. 92, shows the method of doing it. An outer casing is

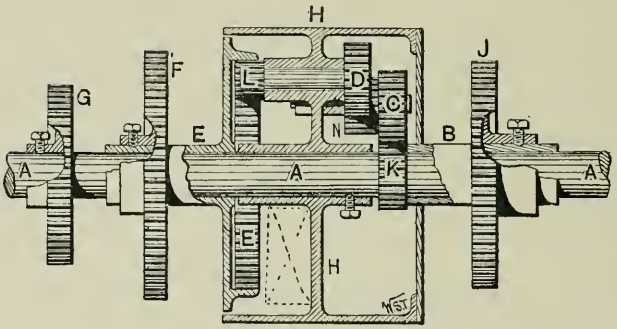


FIG. 93.

used, which covers up the wheels and also serves the purpose of retaining the oil, the projections N distributing it on to the teeth and bearing. Its appearance when on the machine is that of a large-sized coupling, thus occupying very little space, and in addition it is practically noiseless.

In Fig. 93 is represented Curtis and Rhodes' patent as made by John Hetherington and Sons and Platt Brothers, which overcomes effectually the disadvantages of Houldsworth's motion. It retains the epicyclic principle in the train of wheels used, but instead of bevel wheels small pinions are employed. The number of these wheels that are

necessary will, perhaps, at first sight, cause the reader to think that the advantages of the motion have been obtained at the cost of greater noise and friction, and more complications than existed in the older motion. That such a conclusion, however, would be erroneous, will be seen as the description proceeds. In Fig. 93, A is the driving shaft, and on it is fixed the wheel G for driving the spindles at a constant speed; on A is also securely fastened a disc H, which therefore revolves with the shaft, the disc is specially prepared to carry a stud, on one end of which is fixed a wheel L, and on the other end a wheel D; the latter is connected to the wheel K through a compound carrier N and C. The wheel K, and its long boss B, it will be noticed, are loose on the driving shaft, and therefore the wheel J, which is fastened on the boss B, and is driven from the cone drums, is able to transfer this motion to the wheel L through the train of wheels mentioned. The pinion L gears with an internal wheel E, which is loose on the shaft A; the long boss of E has fixed to it the wheel F, from which the bobbins are driven. The connection of the bobbin wheel F with the cone drum can therefore be clearly traced through the motion. Now let it be supposed that the disc H is disconnected from the shaft A, and that A is driven, it will then be an easy matter to see that the wheel J will drive the wheel F through the wheels K, C, N, D, L, and E. The direction of rotation of each wheel can also be followed, which shows F to revolve in the same direction as the shaft A; its speed, however, would be rather slow, moreover the revolution of all this gearing would result in considerable wear and tear and noise, but such conditions do not exist in the motion; they are practically neutralised by fixing the disc H to the shaft, thus causing it to revolve with it. This revolution of H

carries round the wheels D, N, and C, and as C revolves in the same direction as K, and *almost* at the same speed when the bobbin is empty, it follows that there is scarcely any movement of the gearing within H; consequently wear, tear, and noise are reduced to a minimum. During the revolution of H the pinion L will be carried round, and the mere fact of its teeth engaging with E will cause E to be carried round at the same speed; E will also receive a slight additional speed, owing to the small gain existing in the gearing of the wheels. As the bobbin fills, the wheel J will be reduced in speed and the wheels within H will naturally increase in speed, but the amount is never sufficient to result in any appreciable wear and tear, the whole design and the arrangement of the wheels being such as to reduce this probability to the smallest degree. The motion is balanced by placing a weight on the opposite side of the shaft to that occupied by the wheels L, D, etc., so that any tendency to vibration is entirely neutralised.

The speed of the bobbin can readily be determined: it depends upon the excess speed given to the internal wheel E, and this excess speed can be found by subtracting the speed of C (due to its being carried round by H) from the speed of K, and following this through the train wheels to E. For instance—

$$\text{Revs. of J} - \text{revs. of A} \times \frac{\text{K} \times \text{N} \times \text{L}}{\text{C} \times \text{D} \times \text{E}} = \text{excess revs. of E.}$$

Now E has the same number of revolutions as the shaft A, plus this excess speed, so that the speed of E or F equals—

$$\text{F} = \text{revs. of J} - \text{revs. of A} \times \frac{\text{K} \times \text{N} \times \text{L}}{\text{C} \times \text{D} \times \text{E}} + \text{revs. of A.}$$

Very complete arrangements are made for lubricating

the motion, and as it is entirely covered in by projecting flanges on the disc H it is thoroughly protected from dirt and prevented from causing injury to those attending to the machine.

In Fig. 94 another excellent motion is shown (Tweedale's patent), which fulfils all that is claimed for it in overcoming the defects of the old sun-and-planet motion. It is an epicyclic system of gearing, and bevel wheels are retained to effect the desired transfer of motion to the bobbins. Referring to the drawing, A is the driving shaft, B the wheel driven from the cone drums, C the bobbin wheel

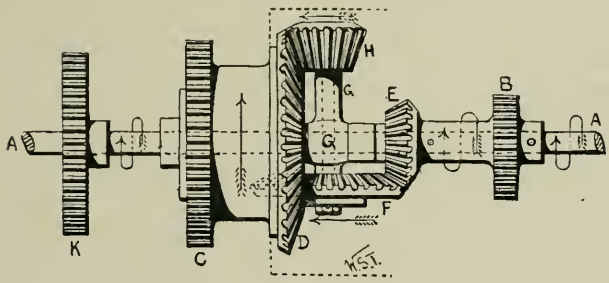


Fig. 94.

from which the bobbins are driven, and K the spindle wheel. The direction of motion of each part is clearly indicated in the sketch by the arrows. Attached to the boss of the wheel B is a bevel E, both of which revolve at the same speed, and run loose on the shaft A, and in the same direction; E gears into a bevel F, carried by a stud which passes through the driving shaft, whose other end carries a bevel H; this gears into a large bevel wheel D, to the enlarged boss of which is fixed the bobbin wheel C. The two latter wheels revolve as one, and run loose on the shaft. The action of the motion can now be made

clear. As the shaft A revolves, it carries bodily round with it the wheels H and F, and in so doing will impart a similar motion to the bevel D; but in addition to this, the driving through B from the cone drums will give a motion to H round the centre of the stud on which it is carried, which will considerably modify the motion given through the bodily motion of H and F. The combination of these two movements enables the bobbin wheel C to be driven at the required speed, and also in the same direction as the shaft. This brief statement is, however, not sufficient to explain the principle of the motion, and as it possesses one or two features of interest it will be advantageous to examine it a little more in detail, in order to see why such a result can be obtained, and more especially why the direction of motion should be as described.

C is the wheel through which the bobbins are driven, and therefore a resistance is offered to the driving of D, and it remains stationary until some force acting upon the wheel D sets it in motion by overcoming the resistance. Now the shaft A carries round the cross shaft G at its own speed, say 400 revolutions, but this motion can have no effect directly on D simply because the bevel H commences to yield instead of D, and H transfers its motion to F and so on to the wheel B. Owing, however, to the direction of the axial revolution of F and the direction of the revolution of the cross shaft, B would not revolve at a great speed because the two movements partially neutralise each other.

What is now needed is to drive B at such a rate and with sufficient power to revolve H in the opposite direction to that given to it through the movement of the cross shaft. When H is thus driven it will cease to move on

its axis, and yet the cross shaft carries it round, consequently it takes D with it and the bobbins are driven through C. The formula is very simple, and depends on the same formula as laid down on p. 141.

$$\text{Revs. of A} - (\text{revs. of A} - \text{revs. of B}) \times \frac{\text{E} \times \text{H}}{\text{F} \times \text{D}} = \text{revs. of C.}$$

$$\text{As a rule } \frac{\text{E} \times \text{H}}{\text{F} \times \text{D}} = \frac{18 \times 30}{16 \times 48} = \frac{7}{10}.$$

If this be condensed into symbols where the speed of A $= m$, the speed of B $= a$, the speed of C $= n$, and the ratio between the wheels

$$\frac{\text{E} \times \text{H}}{\text{F} \times \text{D}} = r,$$

we get

$$n = m - (m - a)r.$$

By substituting actual speeds and wheels in the formula just given, it will be an easy matter to find the speed of the bobbin wheel C (which is part of D) and from it the speed of the bobbins.

The dotted line shows how the motion is covered in to prevent accidents to workers. The lubrication of the various parts is well arranged for, and the whole is well balanced, so that friction is reduced to a minimum, and the strain on the cone drum strap diminished considerably.

The next example is the one given in Fig. 95. Its essential features are as follows:—A is the driving shaft, to which, as usual, the spindle wheel H is fixed. A little farther along the shaft is also fixed a wheel B, which gears into a wheel E, carried by a disc C; E is one of a compound pair of wheels E and F, both of which are cast together and work on the same stud N; F gears into a wheel D, which runs loose on the shaft A. Cast upon D is a long boss, upon which is fastened the bobbin wheel G. We

thus see that G is driven direct from the shaft, and by following the gearing we shall notice that it runs in the same direction as A, so the motion fulfils its principal object in reducing friction to the lowest possible point. The connection with the cone drums is made through the wheel J, which is set screwed to the boss of the disc C, the disc running loose on the shaft A, and in the same direction. By this means the wheels E and F are carried bodily round the shaft A, and by this action influence the speed

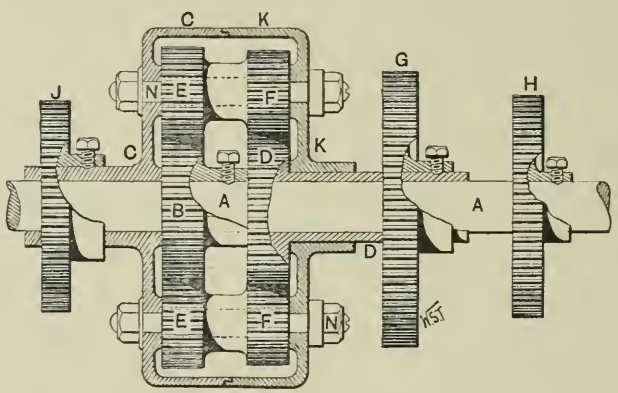


FIG. 95.

of D and consequently G—and it will be noticed that this action is one which does not interfere with D revolving in the same direction as the shaft.

The whole motion is of such a simple character that it can easily be understood, and the following remarks be readily understood: B has 30 teeth, E and F 18 each, and D 33 teeth. The gain between B and D is therefore—

$$\frac{30}{18}\times\frac{18}{33}=\frac{30}{33}=\frac{10}{11}.$$

Now if C be revolved at the same speed as B, E and F will

have a "relative" motion, which will result in D revolving at exactly the same speed as the shaft. If C be slowed, D will lose in speed by an amount equal to the proportion in which B is less than D, which is $\frac{1}{11}$; so that if C revolves eleven revolutions less than B, the wheel D will have one revolution less than A. In the same way any increase in the speed of C over B will cause an increase in the speed of D in the same proportion as above, viz. $\frac{1}{11}$, so that if C revolves eleven revolutions more than B, D will revolve one more than A; C, however, is never required to run quicker than A. From this statement it is an easy matter to calculate the speed of the bobbin wheel G, and from it that of the bobbin.

The motion is thoroughly cased in by C and K, and special attention has been paid to the arrangements for lubrication through the studs N. Wear and tear due to friction is almost eliminated, and comparatively very little motion of the wheels E and F can take place, so that the gearing adds little, if anything, to the noise of the frame. In all the examples that have been given, one great advantage is the more regular winding that results from their working. The power hitherto transmitted through the strap of the cone drums has always had a tendency to cause slippage, but since the important factor of friction has been so considerably reduced this element of uncertainty in winding has almost disappeared, and the bobbins can now be relied upon to start at the same time with the spindle and maintain the true relationship of speed throughout the building of the bobbin.

Traverse Motion for Bobbin.—The next feature of the fly-frame to which attention will be directed is that of the traverse or reversing motion. Its functions are of a very important character, and therefore before describing

it, it will be necessary to make a few preliminary remarks, in which the reason for its use will be defined and illustrated. In the building of a bobbin, the operation must be performed in such a way that no change of shape can take place in it, and also so that its form shall permit of its being handled and carried from one machine to another without causing any damage to the roving. There are three methods of fulfilling these conditions, viz. building a bobbin by a quick traverse motion; using bobbins with flanged ends; and building bobbins formed with conical ends on the cotton itself as the bobbin is filled. All these methods are practised in the processes of cotton spinning, but in the machine under discussion the latter method is the one usually adopted.

The extreme weakness of the roving renders it imperative that very light bobbins be used, in order that they may permit the roving to be taken off from them when in the creel. Plain barrels are therefore used, and the roving is wound on in a manner that gives the result shown in Fig. 96. An examination of this sketch will show the necessity of shortening the traverse from A, B to C, D, in order to give a conical form to the ends. The bobbin rail must therefore be reversed earlier after each successive layer has been added. (It is from this fact that we get the term reversing motion.) Incorporated with the reversing motion is the arrangement for moving the straps forward along the cone drums as the bobbin fills. Each additional layer requires a slower speed than the preceding one, and consequently each change of the traverse automatically removes the strap to the required position on the cone drums, the movement of course being equal for each layer. Now since the hank of the roving may vary through a long range it will be necessary, when a coarse

hank is being wound on the bobbin, that each layer will require a greater lateral movement of the strap than when a finer hank is used. This is obvious: for instance, suppose the strap starts and finishes the same for a fine and a coarse hank bobbin; the number of layers in the diameter of the bobbin containing the finer roving will be many more than the layers in that of the coarse roving, and consequently the larger number of movements of the strap must be correspondingly reduced in amount in order to equal the fewer movements which occur in building the coarse roving bobbin. For example:— Suppose a 2-hank roving be wound on a bobbin 5 in. in diameter, there will be about 120 layers, and each layer will require a movement of the strap. The amount of this movement on a drum 30 in. long will be $\frac{30}{120}=\frac{1}{4}$ of an inch.

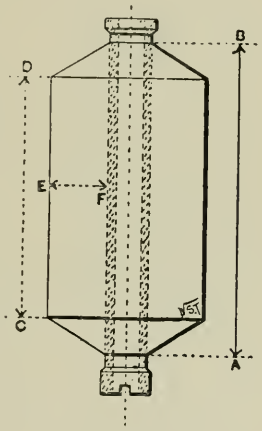


FIG. 96.

If a 5-hank roving be wound on a bobbin 5 in. in diameter, there will be about 160 layers; each layer will require a movement of the strap of $\frac{30}{160}=\frac{3}{16}$ of an inch. This lessened movement is arranged for in the reversing motion.

Another feature quite evident in connection with the number of layers or coils in the length of the traverse is, that for coarse roving the movement of the rail must be much quicker than for fine rovings, and an alteration will therefore be required when a change of roving is made. This point will be dealt with more fully at a later stage. It is sufficient to mention here that if a 2-hank roving has

twelve coils per inch lift, a 5-hank roving will have 23 coils per inch lift; this means that the bobbin rail will make its traverse at only a little over one-half the speed for a 5-hank roving as compared with the 2-hank roving.

It will also be obvious, especially on reference to the gearing plans of the machine in Fig. 81 and Fig. 97, that the coils depend on the speed of the cone drums, the rack being driven from this point; and, as this speed is a varying one, it would seem to follow that the pitch of the coils on each layer would vary. We certainly do get a slower traverse, but at the same time the bobbin is slowed to the same extent, and consequently the pitch of the layers remains constant throughout the bobbin.

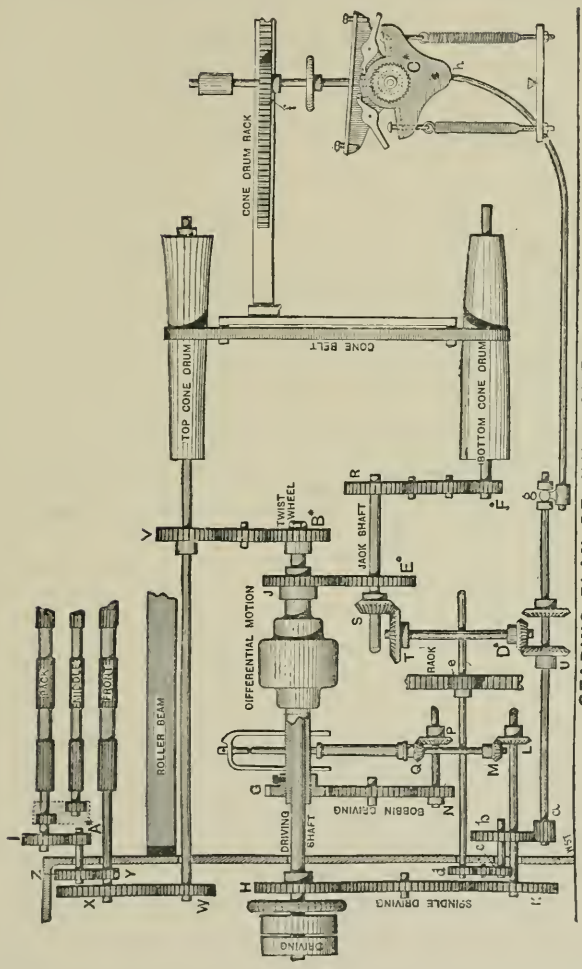
The actual building of the bobbin or traverse of the bobbin rail is performed by the bottom cone drum, through the wheels F, R, S, T, D, U, and the train of wheels leading up to the rack. The reversing of the traverse is performed by the reversing motion, whose position on the machine is shown at C in Fig. 97; its action is such that at the finish of the traverse the bevel U is thrown out of gear with D, and the other bevel is brought into gear with it. At the same time an effect is produced which causes a lateral movement of the cone drum rack, and through it the strap is moved along the drums.

The motion itself will now be described. It is sufficiently complicated to require a careful following of the description and reference to the illustrations.

In Fig. 98 a complete drawing is represented of a well-known form of building or reversing motion. Explanatory sketches also are given in Figs. 99 and 100, which will enable the description to be more easily understood.

It will be remembered that the motion has a threefold purpose, viz. it alters the position of the strap on the

cone drums so that the bobbin is slowed in speed as it



GEARING PLAN OF FLY FRAME.

FIG. 97.

enlarges in diameter: this action gives it the character of

a building motion—a name sometimes applied to the whole arrangement. It regulates and reverses the traverse of the bobbin or lifting rail, and is frequently called the "traverse" or "reversing" motion because of this action. It makes conical ends on the bobbin, by causing the reversing arrangement to take place a little earlier as each layer is added to the diameter.

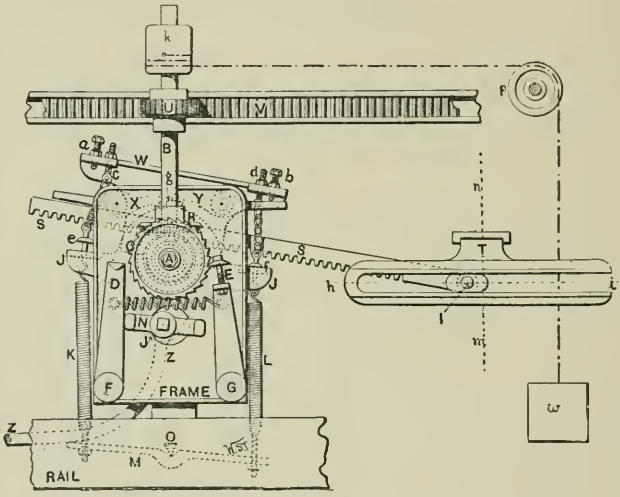


FIG. 98.

Each of these effects will be noted separately. The first-named is effected through the upright shaft B and the wheel U, which moves the long rack V forward in its slide. The connection of the rack with the strap forks gives the required movement to the strap on the cone drums. The second effect is obtained by an oscillating movement of the cradle J about the centre A; this gives a backward and forward motion to the rod Z, which ultimately puts the bevel wheels in and out of gear with

D. The third action is governed by a small pinion A (see R, Fig. 99) gearing into the rack S, and its revolution altering the position of the pin I in the slide T.

The slide T is the governing element in all three motions. It is attached to a rail which is connected directly to the bobbin or lifting rail, and the vertical movement along *m*, *n*, which it thereby receives, controls each of the actions mentioned above. The whole consists of a frame, firmly fastened to a cross rail. The frame contains a centre boss A, on which are placed two cradles

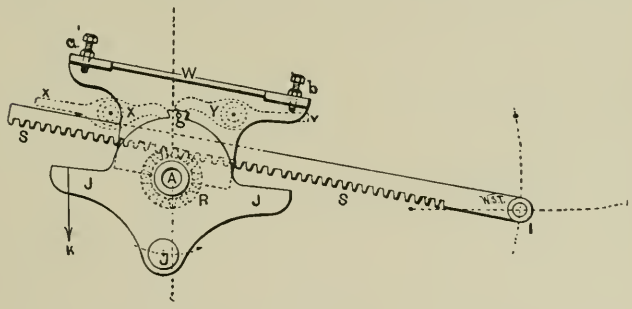


Fig. 99.

J and W, in a manner that leaves them perfectly free to oscillate independently of each other. On a stud A, which passes through a hole in the boss, is fixed a ratchet wheel C, and also a bevel, which gears into the bevel H on the upright shaft B. A chain weight at *w* passes over a guide pulley *p*, and is wound on a bowl *k* keyed to the upper part of the shaft B. The weights *w* will naturally tend to cause the shaft B to revolve, and consequently the ratchet wheel C, but this action is prevented by detents or catches D or E, which engage in the teeth of C, and it is only when these are freed from contact with it that the weight *w* gives motion to the shaft. Such a motion, when

produced, turns the wheel U, and the long rack V is moved forward.

The method of releasing the ratchet can now be explained. The rack S passes through a slide, which forms part of the upper cradle W. Its other end is connected to the pin I, which slides in the guide T. The up-and-down movement of the rail gives an oscillating motion to the cradle W round the centre A. On the cradle are fixed two sets of screws *a*, *b*, and *c*, *d*. The first pair are for releasing the tumbler or pigeon catches X and Y, while the second pair are connected with special hooks *e* and *f*,

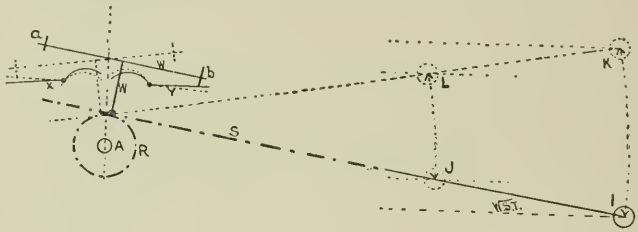


FIG. 100.

to which latter are attached strong springs K and L. The springs are held by the ends of a cross piece M, which is centred on a knife-edge at O carried by the rail. It will now be seen that the oscillations of the cradle W will have the direct effect of putting either of the springs in tension according to the direction of its movement; for instance, if *d* moves upwards, the hook *f* will be free from the cradle J, the tension in the spring L will draw the opposite end of M downwards, and when the projection on the hook *e* prevents further movements by its coming into contact with J, the spring K will be stretched and put into tension, thereby exercising a strong pressure on J, tending to turn it round its centre A. A projection on *g* on the upper

part of J enables the tumbler catch X to prevent any movement of J, and it is only when the lifting rail has reached the limit of its traverse that the oscillation of W brings the setting screw *a* into contact with X, the downward pressure of *a* causing the tumbler to be freed from the projection *g*. Directly this occurs the tension of the spring K produces a quick movement of J, which bodily moves round the centre A; the lower part of J carries a double finger N, and as J suddenly changes position this finger, moving with it, gives a smart blow to the catch E, and releases it from the teeth of the ratchet wheel C. When this release takes place the weight *w* instantly commences to turn the ratchet wheel, but only a fraction of a revolution is permitted, for the spring which connects the two catches D and E instantly brings D into the path of the teeth, and prevents more than a regulated amount of movement taking place. The amount which is obtained is imparted through the bevels H to the upright shaft B and the wheel U. The long rack is correspondingly affected, and produces the change of the strap which alters the speed of the bottom cone drum. The same action is repeated during the descent of the rail; *b* releases the catch Y, which engages with the projection *g*; the cradle J under the pressure exerted by the spring L, oscillates backwards, and in doing so forces D out of contact with the teeth of the ratchet, and permits E to be brought into action. This alternate effect, due to the oscillation of the cradle W, continues throughout the building of the bobbin.

The to-and-fro motion of the lower cradle J is taken advantage of to obtain the reversing of the lifting rail. Attached to the lower portion of J is a rod Z, which is connected with the bevels that gear into the bevel D. As the change is therefore made in the position of J the rod

Z is moved at the same time, and a change in the direction of the movement of the rail is obtained.

In regard to the ratchet wheel, it will be seen that the amount of movement given to the long rack depends primarily upon the number of teeth contained in C. A smaller number of teeth will be required when a coarse hank is being wound than when a fine hank is used. The quickness of the movement of the catches prevents more than a single tooth of the ratchet "escaping," no matter (within reasonable limits) how small the pitch of the teeth may be. As a rule in all frames the catches are set in relation to each other, so that only half a tooth of the ratchet escapes, the catch E being made with a setting arrangement, which allows a regulation to be made for this purpose.

We can now deal with the part of the motion which affects the shortening of the traverse, and produces the taper of the ends of the bobbin. On the stud A, which carries the ratchet C, is fixed a small pinion R (Fig. 99). Each escape of C causes a similar movement of R, and as it gears with the rack S it moves it forward. This alters the position of the pin I in the slot of the guide T. Now it will be seen that the position of this pin regulates the time when the setting screws A and B depress the tumblers and relieve the cradle J. When the bobbin commences, the lift from I to K is arranged to produce the change at the termination of the up-and-down lifts. Each successive change moves the pin forward, and thus shortens the leverage of the rack about the centre A. As a consequence the setting screws A and B will be brought into contact with the tumbler catches at an earlier period of the traverse, and the reversing will be performed before the completion of the original traverse. Extreme positions are shown in

the Diagram 100, and it will readily be understood that the traverse from J to L will have exactly the same effect in oscillating the cradle W to the same extent as when the traverse was from I to K. The sketch shows, by means of full and dotted lines, the positions of the cradle, catches, and rack, for each extreme position.

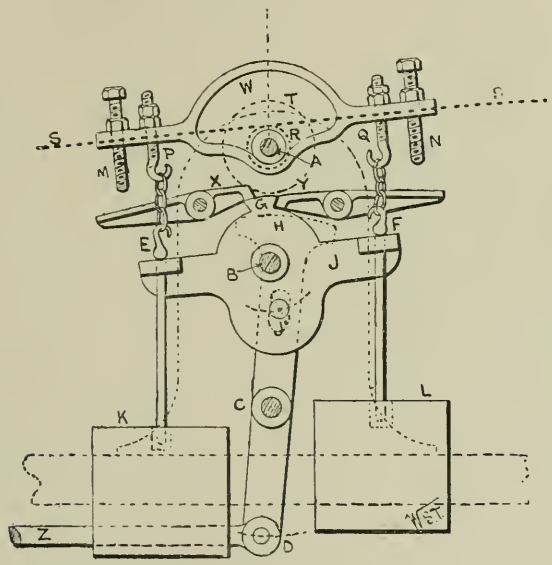


FIG. 101.

Another form of reversing motion is represented in Fig. 101. Its principle of action is exactly the same as in the example just described, but it differs in one or two features of a practical character from the arrangement in Fig. 98.

The upper cradle W is centred on the stud A ; the rack S passes through slide brackets fastened to W, so that the cradle oscillates with the rack about the centre A. On the

stud A is fastened the ratchet wheel T, the bevel wheel for giving motion to the upright shaft (whose centre only is shown), and also the wheel R, gearing into the rack S. The oscillation of the cradle W causes the set screws M and N to relieve the tumbler catches X and Y alternately. This action sets free the lower cradle J, and it makes a short sudden movement about its centre at B. This movement causes a pin fixed in its lower part at J^1 to move the lever C sideways, and in doing this the upper part H of C knocks the catch which holds the ratchet wheel out of position, and permits the ratchet to make the necessary amount of movement. The releasing lever is centred at C; its other end D is attached to the rod Z, which puts the reversing bevels in and out of gear.

It will be noticed that the two cradles, W and J, are on different centres. This arrangement is one that shows a variation in the practical way of obtaining the same result, and as they both give equally good results comparisons are unnecessary. Another difference of more importance consists in the substitution of the weights K and L for the springs in the preceding motion. Weights have the advantage of being of a definite character, and always remaining so. Springs are not so well defined in the pressure they exert, and they are liable to change through continual use, unless very well made. Weights, however, have the disadvantage of their whole effect being brought to bear suddenly on the upper cradle, and when the tumbler-catch is relieved the full force of the weight K or L produces the change of the cradle J. The shock of the sudden stoppage of the fallen weight is a distinct disadvantage, which in the case of a spring is almost absent. A spring exerts its full pressure at the moment of the release of the cradle, but the pressure of the spring

is reduced as the cradle yields to it, and when the cradle reaches its extreme position the spring is free from tension. As the cradle W oscillates, it will be observed that alternately the full pressure of the weight or spring comes upon it. The pressure exerted is considerable, and as it acts either at P or Q it produces a frictional effect between the rack and the pinion, which prevents the pinion turning freely. The drag weight *w* in Fig. 98 is the only means that enables R to revolve; consequently a very heavy weight is required here to overcome the friction, and even then a slight delay is occasionally caused, which prevents the strap from being moved in order to wind on the new layer, and tight winding is the natural result. It is only fractional in its character, and scarcely observable, but it is one of the many small irregularities that may interfere with perfect winding.

A well-known firm of machinists, Howard and Bullough, have successfully introduced a method of relieving the upper cradle of the pressure mentioned above. It is illustrated in Fig. 102, in which a reversing motion is shown complete. Both cradles are on the same centre as the ratchet wheel. Now, instead of the weights H and H^1 hanging from the upper cradle, an arrangement is introduced which is entirely unconnected with them. A hanging lever A, fastened to the guide B, has its lower end fitted with stop screws A^1 and A^2, so that during its rise and fall they come into contact with the end of a lever C, whose fixed centre is on the framing at D. The weight-hooks E and E^1 pass through holes in the projections F and F^1 of the lower cradle. They are also prepared with stop-pieces, which fit special notches cut in the lever C. As the lever C oscillates, it alternately raises one of the weights and frees the other. For instance, suppose the

lifting rail is moving upwards, the stop A^2 lifts up the end of the lever C; the notch coming under the stop on the hook E raises the weight H, and thus takes its pressure off

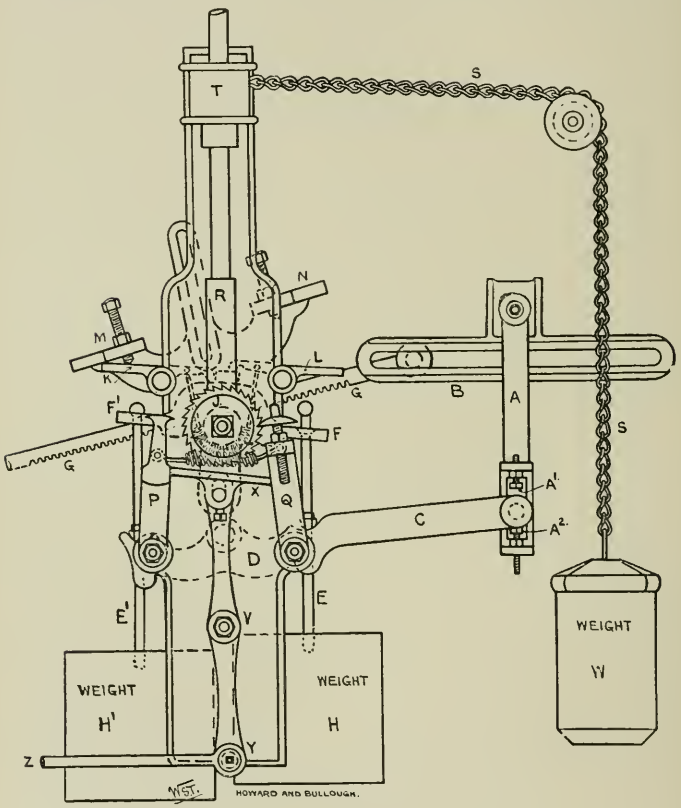


FIG. 102.

the lower cradle. At the same time the other end leaves the stop on E^1, and the weight H^1 is then compelled to hang from the cradle at F, and in this position it is ready to produce the

change which results in the escape of the ratchet wheel. The opposite effect is obtained on the descent of the lifting rail, whereby H^1 is relieved, and H is brought to bear on the cradle. It will be seen that the upper cradle is uninfluenced by the weights, and therefore the rack and pinion work freely with each other. A normal drag-weight W only is required to turn the upright rod as a tooth escapes ; the change is instantaneous, and all chance of delay from this cause is eliminated.

In view of the importance of obtaining as great a degree of freedom from friction the arrangement shown in Fig. 103 is used by Brooks and Doxey. Its main features will be readily understood if the previous descriptions have been closely followed. The diminishing or tapering rack is shown in its middle position, and the top cradle has moved so that the left-hand weight (not shown in drawing, but the weight hook indicates its position) is already hanging from the bottom cradle ready to pull it over immediately the adjusting screw on the top cradle comes down low enough to release the pawls that hold the bottom cradle in position. The movement of the bottom cradle actuates a vertical lever fixed on its shaft, and the lower end of this lever is connected to a bracket fastened to the reversing shaft or rod. This bracket carries an arm hollowed out at each end into which the lower extremities of the levers carrying the ratchet catches or pawls are inserted. As the lower cradle rocks to and fro due to the rise and fall of the lifting rail of the frame, the dished arm will act on the ends of the levers alternately and push the catch out of gear with the ratchet wheel, and at that moment of freedom the weight hanging from the winding wheel boss will move the diminishing rack forward and so through the rack wheel give motion to the cone drum rack. Also at the same time, the displacement of one of the catch lever

arms puts the spring between the two arms in tension, and the other catch lever arm is pulled into gear with the

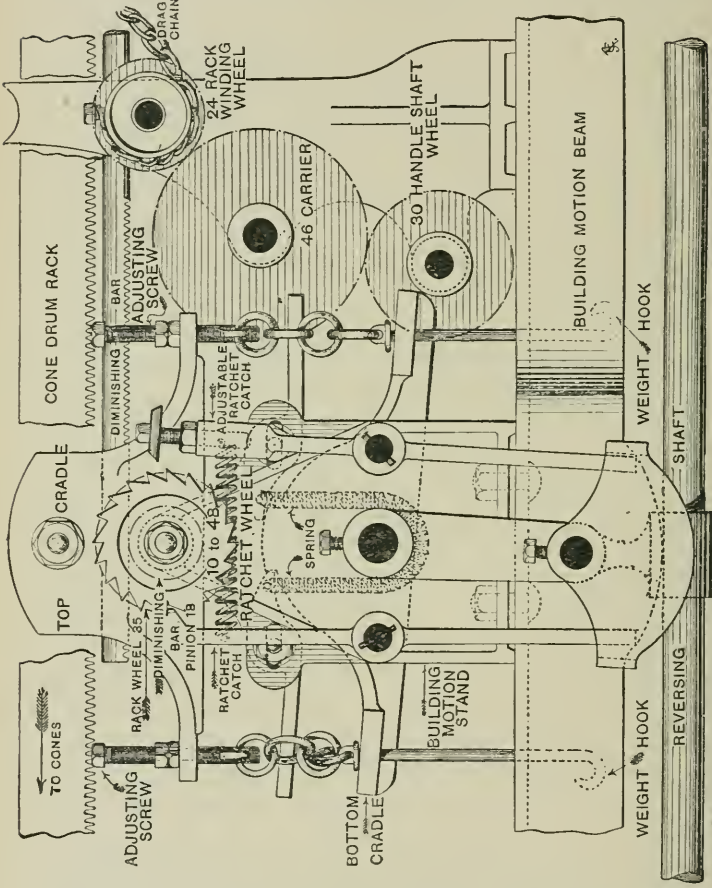


FIG. 103.

ratchet teeth and so prevents further movement. It will be noted that the drag chain is attached to a wheel separate from the building motion, and also that the winding back

operation is done through the gearing shown in shaded lines and in a position convenient to the worker.

To eliminate probable errors and obtain as great a degree of accuracy as possible in the mechanical details of the machine, attention is directed to the method of driving the bobbin-shaft wheel at the time of its making the traverse.

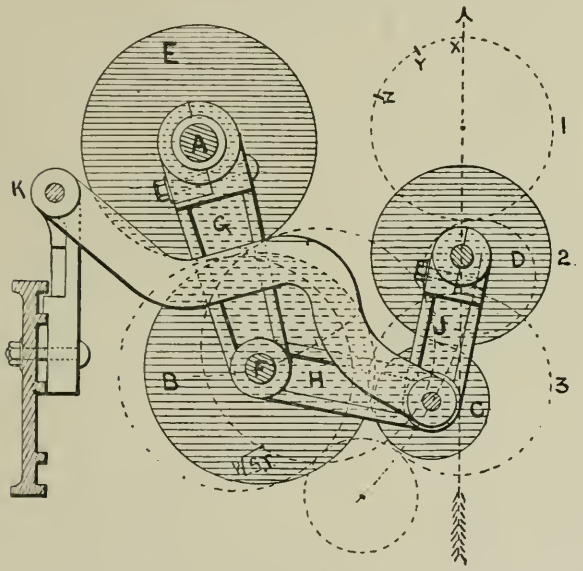


Fig. 104.

In several makes of machines an arrangement is adopted consisting of four wheels, as shown in Fig. 104, wherein A is the driving-shaft wheel and D the bobbin-shaft wheel. This latter wheel, through its being carried by the top rail, is compelled to move vertically, as shown by the arrow. In consequence of this movement the wheels B and C, which connect it to E on the driving shaft, must be carried on movable centres in order to compensate for the vertical

motion of D. The usual method of doing this is to connect B, C, and D by a bell-crank lever in one piece H J; while B is connected to E by the link G. By this arrangement D can readily be moved in the required direction.

A careful examination of the action of this system will show that it presents an epicyclic train of wheels, carried by arms G, H, and J round the centre A. This being so, we shall find that while the centre of D moves vertically, the wheel itself turns slightly on its own axis. This axial rotation is transmitted to the bobbins, and introduces a perceptible variation in the roving; the amount of the turning is shown on the wheel at 1. If X was a point marked on the wheel, it would be found that it would occupy the position Y after three-quarters of the lift had been performed, and the position Z after the remaining one-quarter. The effect of this would be to stretch the roving during the latter part of the up lift, and to produce the opposite result during a similar period of the down lift. (The exact amount cannot readily be calculated, but it is an easy matter to test the question practically; it is then found to give an extreme variation of about 3 per cent, or $1\frac{1}{2}$ per cent on either side of the hank required.)

To overcome the above defect and neutralise the rotation of D, a well-known firm have introduced the improvement shown in the drawing (Fig. 104). Instead of carrying B, C, and D by a bell-crank lever, H and J are made in separate links; at the same time C is also carried by an extra lever, centred at K. The position of this centre is such that the movement thus permitted to C compensates for the axial movement of D, and it is found that with this improvement more regular roving is produced, which demonstrates its effectiveness.

In several other makers' machines the disposition of

the wheels is made to differ from the above. Fig. 105 will show the arrangement: here only three wheels are used, the centres being connected by the links D and E; A is the driving-shaft wheel, and C the bobbin-shaft wheel. As C is moved vertically, the wheel B will describe a circular path round the centre of A, the link D keeping the two wheels in gear. Now this arrangement is also of an

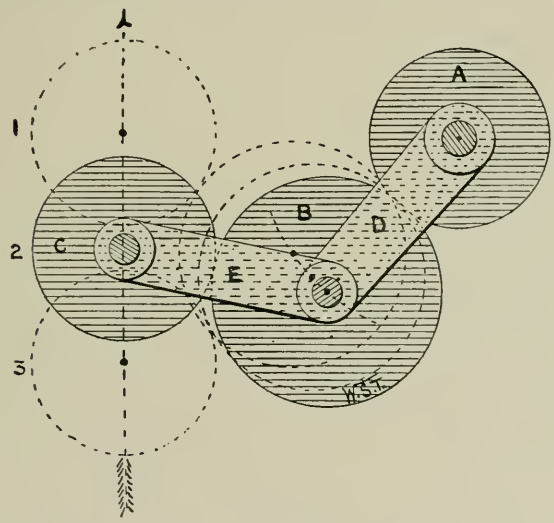


Fig. 105.

epicyclic character; but since it consists of an odd number of wheels (three) instead of an even number, as in the previous illustration, the wheel C is by this very fact prevented from making any axial rotation. In spite of this advantage, however, the movement of wheel C in a vertical direction, instead of a circular one round A as centre, changes the point of contact between the wheel C and B, and so interferes slightly with the speed of A; otherwise it is one

of the best mechanical arrangements known for preventing axial rotation. In both illustrations the extreme movements of each wheel are shown by the dotted lines.

Several minor matters of detail still remain, which are worthy of a little consideration, but the remarks concerning them must of necessity be brief. The foregoing examination into the principles and construction of the fly-frame, however, will enable them to be readily understood without going to undue length in explanation.

A feature that is at first puzzling to the student is the varying speed at which the different lifts take place as the bobbin fills. It will be noticed that the first layer occupies a much shorter time in its performance than the last lift. This is explained when it is found that the gearing which operates the lift is directly connected to the bottom cone drums. The reason for it is also obvious: for it is quite clear that if the layers are wound on quickly, as on the bare bobbin, the lift must be made quick enough to put the layers or coils on at a suitable distance apart according to the hank being wound. When the bobbin increases in diameter the winding is slower, and therefore the lift must be slowed to compensate for this: in fact the connection between the lift and the winding is a direct one, and a reduction in speed of the one must be followed by a similar reduction in that of the other. This explains why the pitches of the coils are constant throughout the building of the bobbin while the lift that lays them is itself altering in speed.

The balancing of the bobbin rail is one of those smaller questions that prove troublesome occasionally, but the present-day machines are carefully attended to now in this respect. The usual method is to hang weights by means of chains passing over pulleys from the rail brackets,

which work in slides on the face of the spring pieces; the amount of the weights is arranged to balance the rail when its bobbins are half-full. In most cases this is a matter of guesswork, but it is sufficiently near for practical purposes. Another method is to attach the weights by means of chains to a lever, which rests under the centre of the rail, and of which the fulcrum is situated as far away as possible in a line with the middle of the lift. This latter method prevents any possibility of the rails sticking in its slides—as is quite possible in the former case, unless great care be taken in forming the slides. An ingenious method was tried some time ago, which provided for the balancing of the rail automatically under all circumstances. The chain, connected to the slide brackets of the rail, passed over guide pulleys, and was fastened to a lever, which carried a weight heavy enough to balance the empty rail. This weight, by means of a screw and ratchet wheel, could be moved along the lever away from the point of suspension of the chain, which was done through the ratchet wheel being acted upon at each up-and-down lift. Greater pressure was in this way exerted by the weight in its new position on the lever, and a well-balanced rail was the result.

When a set of bobbins has been completed, the strap on the cone drums must be wound back to its starting-point. In order to do this it is necessary to raise the bottom cone drum a little, so that the strap is slackened; when this is done by the tenter from the front of the machine, she is able to wind the strap back, ready for the next set. In most machines the two operations, viz. lifting the cone drum and winding back the strap, are performed from the front of the frame, thus saving time and trouble in going round the machine to the back.

Although the point has been mentioned before, it is important the student should thoroughly understand that the full length of the cone drum is not used for all sizes of bobbins : it is only when the ratio between the empty and full diameters corresponds to the ratio between the extreme diameters of the drums that this is the case. We have seen that the form of the drums has been obtained irrespective of the speed of the bobbins, and it will be readily understood that the strap can always start at the same point (no matter what the diameter of the empty bobbin may be), provided the initial speed is made correct for that diameter by arranging suitable gearing between the cone drum and the bobbin shaft. When the bobbin is large enough for the purpose in view, the strap will be on the drums in the position necessary for that diameter ; and it is clear that, for some bobbins, especially in the finer roving frames, very much less than the full length of the drums is utilised.

Ratchet Wheel.—In all fly-frames there is an element of uncertainty in the star ratchet wheel in regard to the number of teeth it ought to contain for different hanks. Experience and trial in most cases settle the matter in the first place, and afterwards the wheels thus found are used for finding others in proportion. Attempts have been made to arrange a table from which the star wheel can be calculated, which depends on the number of layers per inch in the diameter of the bobbin. Approximate results are in this way obtained, but there are so many degrees of tension put into the roving—ranging from soft bobbins to tightly wound bobbins—that very little reliance is placed on any one basis by practical men. These calculations are, however, useful as a guide, and therefore the following extract is given from Mr. W. H. Cook's *Plain Series of*

Cotton Spinning Calculations, in which such a table is published :—

LAYERS PER INCH LIFT

1 hank	=	$\sqrt{}$counts	×	7·5
1·1 to 2 hanks	=	$\sqrt{}$counts	×	8·5
2·1 ,, 3 ,,	=	$\sqrt{}$counts	×	9·5
3·1 ,, 4 ,,	=	$\sqrt{}$counts	×	10
4·1 ,, 5 ,,	=	$\sqrt{}$counts	×	10·5

General Notes.—In bringing to a conclusion the description of the fly-frame, it will be convenient to make a few general remarks on the ultimate results of its work. We have seen how imperative it is that a high ideal of accuracy should be kept in view, and the descriptions will have shown to what extent mechanical action has attempted to attain to this result. It is only when an examination is made of the roving on the bobbin that a correct judgment can be formed of the real work of the machine. Bad work, when it exists, may be traced to the following different causes, viz. faults in the mechanism; faulty setting of rollers, etc., and speeds; carelessness in attending to the machine; faulty rovings, the results of previous operations; and poor cotton. Each of these gives rise to inequalities in the roving, which may be reduced to a minimum with proper care and supervision; but, in spite of all that can be done, there remains the inherent property of the fibre itself to be taken into account, and the apparent impossibility of obtaining ideal mechanical conditions for dealing with it prevents absolute uniformity from being obtained.

Faults in the mechanism are to be seen in broken teeth; too much backlash in gearing; loosened brackets; slides sticking in grooves through friction; slippage of wheels on their shaft, etc. Faulty setting of rollers, etc., and speeds, give rise to a lot of bad work, which at first is

not easily traceable to the real cause; drafting, spacing, and twist are all-important points, which require attention in getting the best results from the cotton and the machine, and, in a measure, the required exactness depends ultimately upon experience and knowledge of the special conditions governing the case.

Carelessness, of course, is responsible for many faulty rovings. If the top rollers are not oiled at regular intervals, or a sticky oil that gums be used, it causes the rollers to momentarily stop, and a thin place is instantly made. Long piecings are a distinct evil. Roller laps increase or reduce the draft, and so alter the hank slightly. Slippage of the cone drum strap occurs through slackness or allowing oil to run on it. Slippage of the bobbins and also the momentary slippage of the flyer occur when it has not dropped into its slot before the machine has started; allowing "single" to go through; and also when a case of "back double" occurs.

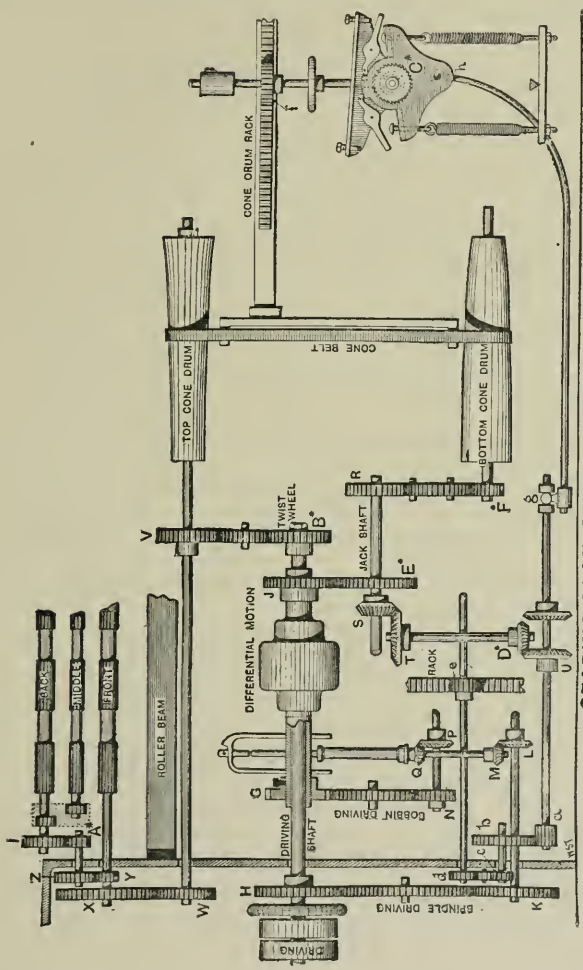
Previous operations are also responsible for bad work. Unequal laps from the scutcher naturally transmit the evil to all future processes, and too much care cannot be insisted upon in attending to this matter. Bad carding and single in the draw-frame lead to inequalities, which the fly-frame cannot get rid of, and therefore they exist of necessity after passing those machines which produced them.

In regard to poor cotton, the inequalities from this cause are to a certain extent expected, but bad judgment in mixing will lead to poor results in the roving and yarn, and of course these can be detected in each process, but the cause is not always so readily found.

Calculations.[1]—An illustration of the gearing part of the fly-frame is given in Fig. 107 (reproduced from page 155),

[1] Full calculations with gearing plans of the chief type of fly-frames are given in the author's book *Cotton Spinning Calculations.*

and for the purpose of the calculations reference may also



GEARING PLAN OF FLY FRAME.

FIG. 106.

be made to Fig. 106 (which is practically the same, with the

exception of the differential motion, and is reproduced from

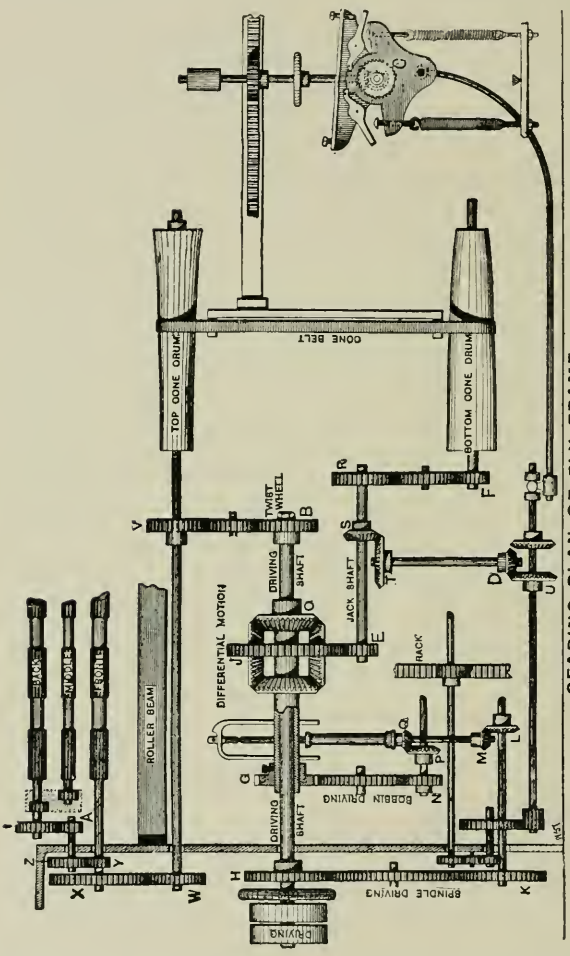


FIG. 107.

page 199). There are six distinct change places, at all of

which alterations can be made to attain or suit various conditions. These are specially marked in the drawing by an asterisk, as at A, B, C, D, E, and F.

We have already referred to the driving of the spindles and bobbins, and shown that they both receive their motion direct from the driving shaft, except the "excess speed of the bobbin," which, of course, is transmitted from the cone drums. This ought to be distinctly noted, as it will prevent much misunderstanding in regard to the purpose of both the differential motion and the cone drums. The rollers are driven from the driving shaft through the twist wheel B, which, it will be seen, also drives the top cone drum. If, therefore, the front roller be altered in speed, the speed of the cone drums will be altered to the same extent; the reason for this will become clear when we make a practical application of the rules.

The bottom cone drum drives the sun wheel of the differential motion as well as the lifting motion. The gearing for the latter can be traced through the following wheels, the top line representing drivers, and the bottom line the driven wheels:—

$$\frac{F \times S \times D \times a \times c \times \quad e}{R \times T \times U \times b \times d \times \text{rack}}.$$

The objects of the change places and the usual extent of the change, in the machine illustrated, are given in the following list:

A is the change place for			Draft . . .	Wheels	35	to	60	teeth
B	,,	,,	Twist . . .	,,	26	,,	48	,,
C	,,	,,	Winding . .	,,	10	,,	50	,,
D	,,	,,	Traverse . .	,,	16	,,	26	,,
E	,,	,,	a change in the dia. of empty bobbin	,,	15	,,	30	,,
F	,,	,,	both traverse and dia. of empty bobbin	,,	14	,,	30	,,

The latter change is one that is very seldom resorted to,

as the other change places do all that is usually necessary. A careful observation of the result of a change in the number of teeth of F will show us that it will affect two features of the bobbin, viz. the tension of the roving and the closeness or pitch of the coils in the traverse. When, therefore, a combination exists of slack ends and coils that are too close together, a remedy may be found in putting on a large wheel at F, which naturally increases the speed of the bobbin and also increases the speed of the lift, thus tightening the ends and making the pitch of the coils greater.

The necessity for the changes may be best illustrated by an example. Suppose a certain hank is being produced on the machine and it is desired to change to a higher hank, the same roving being used in the creel. The necessary changes in gearing are as follows :—

Draft.—This must be altered, in order to make the delivered roving thinner ; A will therefore be made smaller in order to drive the back roller more slowly.

Traverse or Strike Wheel.—This change must be made, because the thinner roving which is now delivered will require to be wound in coils of less pitch than for the thicker roving ; consequently D is made smaller, so that the lift can be reduced in speed.

Winding or Star Wheel.—The thinner roving also requires that C should be enlarged in order that a lessened movement may be given to the rack at each up-and-down lift. There will be more layers per inch of diameter for the finer than for the coarser roving ; therefore, each action of the lift must give a shorter traverse to the rack which moves the cone drum strap ; a larger number of teeth in C will effect this

Twist.—A fine roving has more twist put into it than a

coarse one; B is changed for this purpose, and by making it smaller the speed of the front roller is reduced, but since the speeds of the spindles are not altered more twists will be put into the roving. From this latter change it will be noticed that the speed of the cone drums is also changed, which is a necessary consequence of changing the speed of the front roller: for if the front roller be slowed the bobbins must have the same reduction in speed in order to wind on the smaller amount of roving that is delivered to them.

The following table presents the reader with all the essential particulars required in working out any of the calculations in connection with the fly-frame. They, of course, vary greatly in other machines, but the applications of the calculations are similar:—

		Slubber.	Intermediate.	Rover.	Jack.
A	Draft wheel . . Change	...	...	...	...
B	Twist wheel . . ,,	...	...	...	...
C	Star or ratchet wheel ,,	...	...	...	...
D	Lifter wheel . . ,,	...	...	...	...
E	Jack wheel . . ,,	...	...	...	...
F	Bottom cone end wheel ,,	...	...	...	...
G	Driving wheel for bobbins .	60	60	60	60
H	,, ,, spindles .	56	56	56	56
I	Back roller wheel . . .	60	60	60	60
J	Sun wheel	125	125	125	125
K	Outside spindle wheel . .	58	54	50	50
L	Skew gear wheel for spindles	50	50	50	50
M	Spindle bevel wheel . .	26	26	22	22
N	Outside bobbin wheel . .	50	50	50	50
O	Driving bevel for differential motion	51	51	51	51
P	Skew gear wheel for bobbins .	50	50	50	50
Q	Bobbin bevel wheel . .	26	26	22	22
R	Jack shaft wheel . . .	75	75	75	75
S	Lifter bevel wheel on Jack shaft	24	22	18	16
T	Upright bevel on lifter shaft	51	51	51	51
U	Strike or lifter bevel wheels .	51	51	51	51
V	Top cone drum wheel . .	24	30	30	50
W	,, end wheel .	40	40	34	34
X	Large front roller wheel .	115	115	120	120
Y	Small front roller wheel .	18	18	18	18
Z	Top carrier wheel . . .	90	90	90	90
a	Strike shaft pinion for lifter .	14	14	14	14
b, *c*	Compound carrier for lifter .	70	70	70	70
d	Lifter wheel	100	100	85	85
e	Bobbin rail rack wheel . .	20	20	16	16

(1) Speed of front roller $= \dfrac{\text{revs. of B} \times \text{B} \times \text{W}}{\text{V} \times \text{X}}$.

In a slubber this $= \dfrac{270 \times 41 \times 40}{24 \times 115} = 160$ revs.

(2) Speed of spindles $= \dfrac{\text{revs. of H} \times \text{H} \times \text{L}}{\text{K} \times \text{M}}$.

In a slubber this $= \dfrac{270 \times 56 \times 50}{58 \times 26} = 500$ revs.

(3) Length delivered from the front roller equals–

$$\frac{\text{revs. of B} \times \text{B} \times \text{W} \times \text{dia. of F.R.} \times 3{\cdot}1416}{\text{V} \times \text{X}}.$$

$$\text{In a slubber this} = \frac{270 \times 41 \times 40 \times 1\frac{1}{8}'' \times 22}{24 \times 115 \times 7} = 565{\cdot}7'' \text{ inches.}$$

Or (4) Revs. of front roller × dia. of F.R. × 3·1416
$= 160 \times 1\frac{1}{8} \times 3{\cdot}1416 = 565{\cdot}7$ inches.

(5) Turns of spindle to one of front roller can be found by dividing the speed of spindles by the speed of front roller, which equals—

$$\frac{500}{160} = 3{\cdot}12.$$

Or (6)—

$$\frac{\text{X} \times \text{V} \times \text{H} \times \text{L}}{\text{W} \times \text{B} \times \text{K} \times \text{M}'}$$

$$\frac{115 \times 24 \times 56 \times 50}{40 \times 41 \times 58 \times 26} = 3{\cdot}12.$$

(7) $$\text{Twists per inch} = \frac{\text{X} \times \text{V} \times \text{H} \times \text{L}}{\text{W} \times \text{B} \times \text{K} \times \text{M} \times \text{dia. of F.R.} \times 3{\cdot}1416}.$$

$$\text{In slubber} = \frac{115 \times 24 \times 56 \times 50}{40 \times 41 \times 58 \times 26 \times 1\frac{1}{8} \times 3{\cdot}1416}$$
$= {\cdot}88$ twists per inch.

Or (8) $$\text{Twists per inch} = \frac{\text{speed of spindles}}{\text{length delivered by front roller}}.$$

$$\text{In slubber} = \frac{500}{565{\cdot}7} = {\cdot}88 \text{ twists per inch.}$$

(9) Twist wheel $$= \frac{\text{X} \times \text{V} \times \text{H} \times \text{L}}{\text{W} \times \text{twists per inch} \times \text{K} \times \text{M} \times \text{dia. of F.R.} \times 3{\cdot}1416}.$$

$$\text{In slubber} = \frac{115 \times 24 \times 56 \times 50}{40 \times {\cdot}88 \times 58 \times 26 \times 1\frac{1}{8} \times 3{\cdot}1416} = 41.$$

(10) Constant number for twist $$= \frac{\text{X} \times \text{V} \times \text{H} \times \text{L}}{\text{W} \times \text{K} \times \text{M} \times \text{dia. of F.R.} \times 3{\cdot}1416}.$$

$$\text{In slubber} = \frac{115 \times 24 \times 56 \times 50}{40 \times 58 \times 26 \times 1\frac{1}{8} \times 3{\cdot}1416}$$
$= 36{\cdot}08$ constant number.

(11) $$\text{Twist per inch} = \frac{\text{constant number}}{\text{twist wheel}}$$
$$= \frac{36{\cdot}08}{41} = {\cdot}88 \text{ twists.}$$

(12) Twist wheel $= \dfrac{\text{constant number}}{\text{twist per inch}}$

$= \dfrac{36{\cdot}08}{{\cdot}88} = 41$ teeth.

(13) Total draft $= \dfrac{\text{dia. of F.R.} \times \text{I} \times \text{Z}}{\text{dia. of B.R.} \times \text{A} \times \text{Y}}$

$= \dfrac{1\frac{1}{8} \times 60 \times 90}{1\frac{1}{8} \times 57 \times 18} = 5{\cdot}25.$

(14) Change wheel for draft $= \dfrac{\text{dia. of F.R.} \times \text{I} \times \text{Z}}{\text{dia. of B.R.} \times \text{required draft} \times \text{Y}}$

$= \dfrac{1\frac{1}{8} \times \quad 60 \times 90}{1\frac{1}{8} \times 5{\cdot}25 \times 18}$

$= 57$ teeth in wheel A.

(15) Constant number for draft $= \dfrac{\text{dia. of F.R.} \times \text{I} \times \text{Z}}{\text{dia. of B.R.} \quad \times \text{Y}}$

$= \dfrac{1\frac{1}{8} \times 60 \times 90}{1\frac{1}{8} \quad \times 18}$

$= 300$ constant number.

(16) Draft wheel A $= \dfrac{\text{constant number}}{\text{draft}}$

$= \dfrac{300}{5{\cdot}25} = 57$ teeth.

(17) Draft $= \dfrac{\text{constant number}}{\text{draft wheel A}}$

$= \dfrac{300}{57} = 5{\cdot}25.$

(18) **Hank Roving.**—To find the hank roving it is necessary to take a certain number of yards and weigh them very carefully. When this is done reference can be made to specially tabulated results, on which the hank is denoted at once. If such a table is not available, the hank can be found by the use of proportion. When it is known that 1 lb. (7000 grains) of roving equals 840 yards, and that this is the standard for one hank, it becomes an easy matter to calculate the hank, granted the weight of a certain length is known. For instance, suppose ten yards of roving from a slubber weighs 166·5 grains, then since

7000 grains ÷ 840 yards = 1 hank, therefore 166·5 grains ÷ 10 yards = ·5 hank.

A convenient form of presenting this is as follows :—

$$(19)\qquad \text{Hank roving} = \frac{7000 \times \text{number of yards taken}}{840 \times \text{weight in grains}} = \frac{8{\cdot}33 \times \text{number of yards taken}}{\text{weight in grains}} = \frac{8{\cdot}33 \times 10}{166{\cdot}5} = {\cdot}5 \text{ hank roving.}$$

It frequently happens that changes are made in the gearing under circumstances which enable us to dispense with a long calculation and resort to that of simple proportion. The draft wheel is often found in this way, and from the fact that the difference in the hank of rovings depends upon their weight, and consequently upon the area of their cross-section, we can by noting this obtain several other important change wheels by the following simple methods :—

(20) Draft wheel when changing the hank :

$$\frac{\text{Present hank} \times \text{present change wheel}}{\text{Required hank}}$$

$$\frac{{\cdot}5 \times 57}{{\cdot}75} = 38 \text{ teeth.}$$

The rack wheel, etc., are readily found—by remembering what has just been said about the area of the cross-section of the roving. As this area depends upon the square of the diameter, the rules which follow will be easily understood.

$$(21)\qquad \text{Rack wheel} = \sqrt{\frac{\text{Present rack wheel}^2 \times \text{required hank}}{\text{Present hank.}}}.$$

$$(22)\qquad \text{Twist wheel B} = \sqrt{\frac{\text{Present twist wheel}^2 \times \text{present hank}}{\text{Required hank}}}.$$

$$(23)\qquad \text{Lifter wheel D} = \sqrt{\frac{\text{Present lifter wheel}^2 \times \text{present hank}}{\text{Required hank}}}.$$

$$(24)\qquad \text{Star wheel C} = \sqrt{\frac{\text{Present star wheel}^2 \times \text{required hank}}{\text{Present hank}}}.$$

Production of Fly-frame

The production of these machines depends primarily upon the speed of the front roller and the length of time they work per day or week. A knowledge of these two factors will enable us to obtain very exactly the production of any machine. It is, however, sometimes necessary to be able to draw up a table of productions, and it is also interesting to do so, as showing what the machine is capable of doing under normal conditions. To do this we must know several things: for instance, twist per inch; hank roving; weight of bobbin; revolutions of spindle per minute; and the time lost per set in doffing and piecing. It will be noticed that the speed of the front roller is not required, and it will also be noticed that all the other factors are of a more or less variable character. Such factors are tabulated in the following list for the different machines, and also for various classes of cotton:—

[Table

Machine.	Cotton.	Hank Roving.	Speed of Spindles.	Weight of Full Bobbins.	Time lost in Doffing, etc., per set.	Multiplier for Twist per inch.
Slubber . .	Indian and low American .	·4 to ·8	550	30 oz.	14 min.	$\sqrt{\text{hank}} \times 1{\cdot}3$
Slubber . .	American and low Egyptian .	·8 to 1·2	500	28 oz.	14 min.	$\sqrt{\text{hank}}$
Slubber . .	Good Egyptian Sea Island .	·7 to 1·5	400	26 oz.	14 min.	$\sqrt{\text{hank}} \times 0{\cdot}7$
Intermediate .	Indian and low American .	·8 to 1·2	700	24 oz.	14 min.	$\sqrt{\text{hank}} \times 1{\cdot}2$
Intermediate .	American and low Egyptian .	1·2 to 2·5	680	22 oz.	14 min.	$\sqrt{\text{hank}} \times 1{\cdot}16$
Intermediate .	Good Egyptian Sea Island .	1·5 to 3·5	650	20 oz.	14 min.	$\sqrt{\text{hank}} \times 0{\cdot}78$
Roving . .	Indian and low American .	1·75 to 4	1100	11 oz.	13 min.	$\sqrt{\text{hank}} \times 1{\cdot}5$
Roving . .	American and low Egyptian .	2 to 5	1050	$10\frac{1}{2}$ oz.	13 min.	$\sqrt{\text{hank}} \times 1{\cdot}25$
Roving . .	Good Egyptian Sea Island .	4 to 7	900	$10\frac{1}{2}$ oz.	13 min.	$\sqrt{\text{hank}} \times 1{\cdot}1$
Jack . .	American	4 to 8	1150	9 oz.	13 min.	$\sqrt{\text{hank}} \times 1{\cdot}1$
Jack . .	Egyptian	9 to 14	1120	8 oz.	13 min.	$\sqrt{\text{hank}} \times 0{\cdot}9$
Jack . .	Sea Island	15 to 20	1050	6 oz.	12 min.	$\sqrt{\text{hank}} \times 0{\cdot}95$

While recognising that in no two mills is to be found the same set of conditions, it is worth noting that those given in the table are the result of a thorough investigation in a large number of mills spinning the classes of

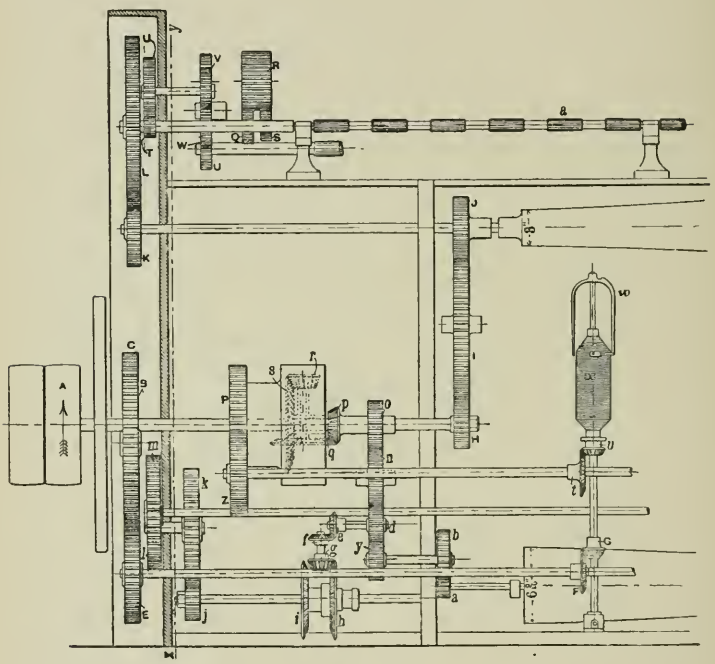


FIG. 108.

cotton named. A long time was spent in noting the time that was spent in doffing on the different machines, together with that lost through piecing, etc. In many cases a machine would be doffed very quickly through six or seven helpers assisting, while the same machine, at the next doffing, would only have two helpers; this necessitated

a large number of observations being taken, and an average

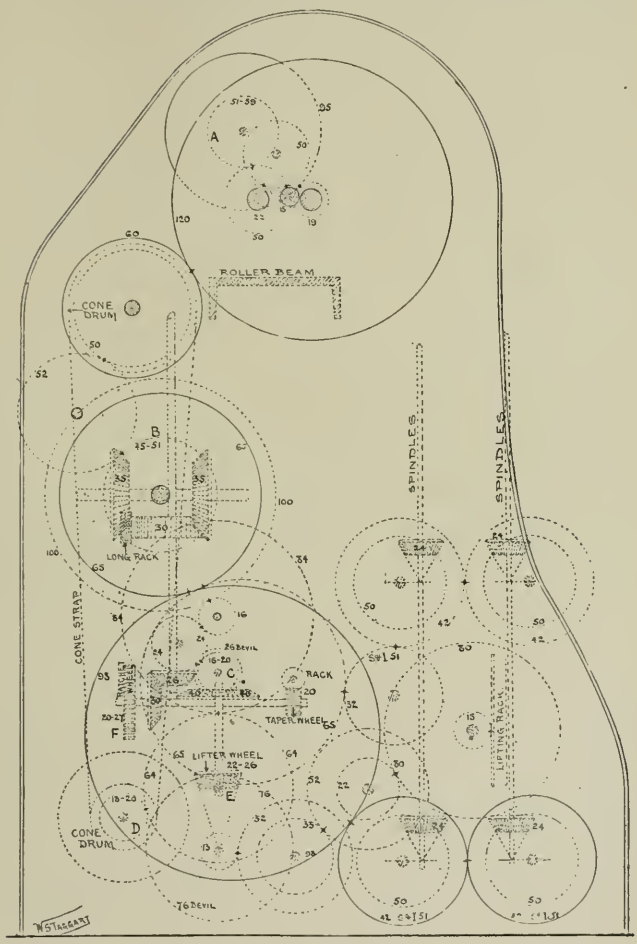


FIG. 109.

of them gave the results as given in the table. The

multiplier for the twist per inch is also the result of a practical investigation in a large number of mills; and, as will be seen, they follow very closely the necessary condition that less twist should be put in as the cotton gets finer in staple.

We are now in a position to calculate the production. In the first place, the time occupied in building the bobbin must be found. This is obtained as follows:—Weight of bobbin in lbs. × hank roving × 840 × 36 = length in inches on bobbin. Length on bobbin × twist per inch = total twist on bobbin.

$$\therefore \frac{\text{total twists on bobbin}}{\text{revs. of spindle per min.}} = \text{minutes the bobbin takes in building.}$$

These three rules can now be incorporated into one. For instance, time to build a set of bobbins equals

$$\frac{840 \times 36 \times \text{twists per inch} \times \text{hank} \times \text{weight of bobbin in lbs.}}{\text{revs. of spindles.}}$$

When we know the time for one set, we can then find the number of sets made in any given time (for instance in 10 hours, which is convenient as a base).

$$\text{No. of sets in 10 hrs.} = \frac{10 \text{ hrs.} \times 60 \text{ mins.}}{\text{minutes to build bobbin} + \text{time for doffing, etc.}}$$

Lbs. per day of 10 hrs. = No. of sets in 10 hrs. × weight of bobbin.
Hanks per day of 10 hrs. = lbs. per day × hank roving.

Example.—Production of a slubbing frame working good Egyptian cotton, hank roving 1·2.

$$\frac{840 \times 36 \times \cdot766 \times 1\cdot2 \times 26}{400 \times 16} = 112\cdot92 \text{ minutes per set.}$$

$$\frac{600}{112\cdot92 + 14} = 4\cdot72 \text{ sets in 10 hours.}$$

$$\frac{4\cdot72 \times 26}{16} = 7\cdot67 \text{ lbs. in 10 hours.}$$

$$7\cdot67 \times 1\cdot2 = 9\cdot2 \text{ hanks in 10 hours.}$$

The waste from fly-frames scarcely ever exceeds 2 per cent, the average being represented as less than 1 per cent. The power required to drive the different machines will of course vary according to the size of the spindles; the following may be taken as an approximation of the number of spindles per horse-power :—

Slubbing frame of	8	in space	40	spindles per horse-power.	
Intermediate frame of	6½	,,	65	,,	,,
Roving ,,	5¼	,,	80	,,	,,
Jack ,,	4½	,,	100	,,	,,

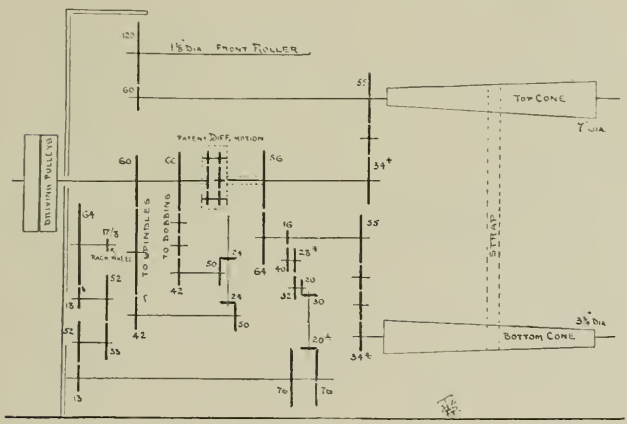


Fig. 110.

For the purpose of assisting those readers who desire to thoroughly understand the gearing of the fly-frame, three drawings are given in Figs. 108, 109, and 110. One (Fig. 108) represents the side view of the full gearing, and from it all necessary calculations can readily be made in the same manner as those given on p. 224.

Fig. 109 represents another well-known maker's arrangement, and whilst giving an end view it is an easy matter to follow through the various trains of wheels. Each

gearing point between the wheels has been marked with a dot, and names given to several features to assist in tracing the driving.

Fig. 110 is given partly as a side-view of the gearing of the previous figure, but primarily as an example of a method of readily making sketches of gearing with the object of saving continual reference to the machines themselves. It might be termed a notebook system, and is far preferable for the purpose than the other sketches of gearing given in other parts of the book.

Drawings that will be of interest to many readers are given in Figs. 111 and 112. They represent a species of standard bobbin for different lifts and the skewers adapted for them. Fig. 111 shows the dimensions suitable for short collars, whilst Fig. 112 is adapted for long collars.

In order to convey some idea of what production can be obtained from the various fly-frames for different varieties of cotton, a table is appended. These productions are of course dependent upon the conditions given at the head of each set, and are based upon actual results gathered from a large number of mills working under the conditions stated.

PRODUCTION OF FLY-FRAMES

SLUBBING FRAMES.—Indian and Low American Cotton.

Speed of Spindles = 550 revs. per min.
Dia. of Full Bobbin = 5¾ in.
Weight of Full Bobbin = 30 oz.

Dia. of Front Roller = 1⅛ in.
Lift = 10 in.
Time lost in Doffing, etc. = 14 min. per set.

Hank Roving.	Revs. of Front Roller.	Turns of Spindle to one of Front Roller.	Twist per inch.	Hanks per Spindle per day of 10 hours.	Lbs. per Spindle per day of 10 hours.	Hanks per week of 56½ hours.	Percentage of Time lost in Doffing, etc.
0·4	189	2·9	0·821	9·4	23·51	53·1	29·2%
0·5	169	3·24	0·919	9·165	18·33	51·78	22·8%
0·6	153	3·55	1·006	8·898	14·83	50·27	18·4%
0·7	143	3·84	1·087	8·52	12·17	48·18	15·1%
0·8	134	4·1	1·162	8·2	10·25	46·33	12·7%

SLUBBING FRAMES.—American and Low Egyptian Cotton.

Speed of Spindles = 500 revs. per min.
Dia. of Full Bobbin = 5½ in.
Weight of Full Bobbin = 28 oz.

Dia. of Front Roller = 1¼ in.
Lift = 10 in.
Time lost in Doffing, etc. = 14 min. per set.

0·8	142	3·5	0·894	9·368	11·71	52·93	15·6%
0·9	134	3·72	0·948	9·054	10·06	51·15	13·4%
1·0	127	3·92	1·000	8·75	8·75	49·4	11·7%
1·1	121	4·11	1·048	8·49	7·72	47·98	10·3%
1·2	116	4·3	1·095	8·23	6·86	46·5	9·1%

SLUBBING FRAMES.—Good Egyptian and Sea Island Cotton.

Speed of Spindles = 400 revs. per min.
Dia. of Full Bobbin = 5½ in.
Weight of Full Bobbin = 26 oz.

Dia. of Front Roller = 1⅜ in.
Lift = 10 in.
Time lost in Doffing, etc. = 14 min. per set.

0·7	158	2·52	0·585	10·6	15·14	59·9	21·7%
0·8	148	2·7	0·625	10·32	12·91	58·3	18·5%
0·9	139	2·86	0·664	10·02	11·14	56·6	16·0%
1·0	132	3·02	0·7	9·75	9·75	55·0	14·0%
1·1	126	3·17	0·734	9·46	8·6	53·46	12·3%
1·2	121	3·3	0·766	9·2	7·67	52·0	11·0%
1·3	116	3·44	0·798	8·93	6·87	50·45	9·8%
1·4	112	3·57	0·828	8·7	6·22	49·1	8·9%
1·5	108	3·7	0·857	8·475	5·65	47·8	8·1%

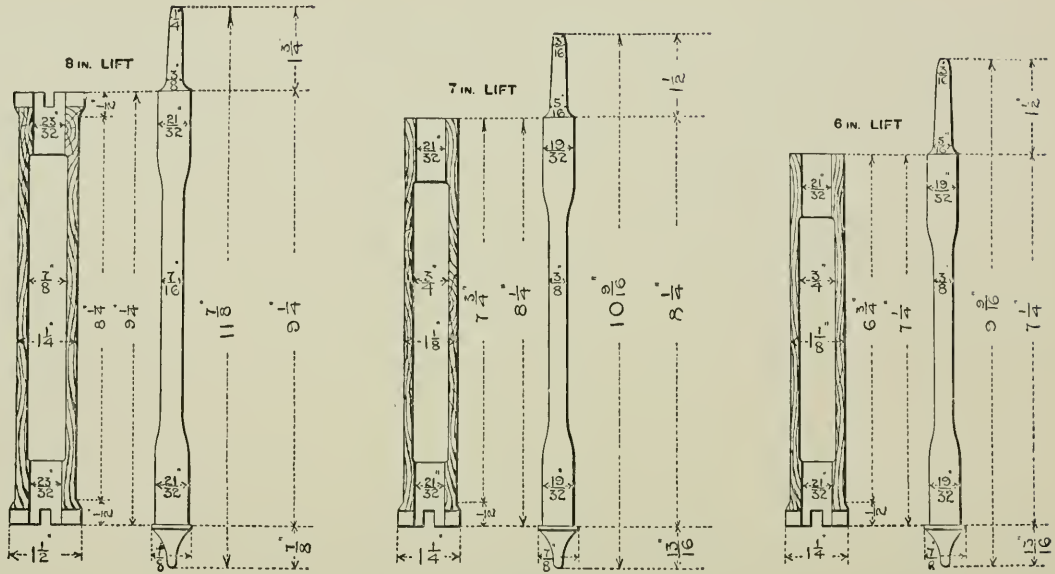


FIG. 111.

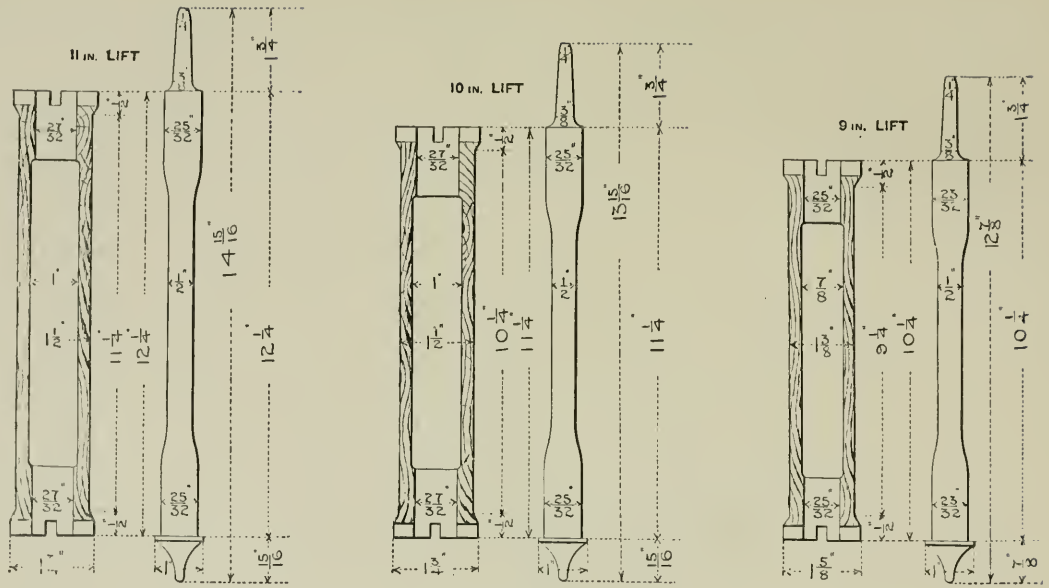


FIG. 112.

INTERMEDIATE FRAMES.—Indian and Low American Cotton.

Speed of Spindles = 700 revs. per min.
Dia. of Full Bobbin = 4½ in.
Weight of Full Bobbin = 24 oz.
Dia. of Front Roller = 1⅛ in.
Lift = 10 in.
Time lost in Doffing, etc. = 14 min. per set.

Hank Roving.	Revs. of Front Roller.	Turns of Spindle to one of Front Roller.	Twist per inch.	Hanks per Spindle per day of 10 hours.	Lbs. per Spindle per day of 10 hours.	Hanks per week of 56½ hours.	Percentage of Time lost in Doffing, etc.
0·8	198	3·78	1·07	10·968	13·71	61·92	21·0%
0·9	187	4·00	1·137	10·67	11·85	60·28	18·4%
1·0	176	4·24	1·2	10·38	10·38	58·64	16·0%
1·1	169	4·44	1·258	10·13	9·2	57·24	14·3%
1·2	162	4·63	1·314	9·86	8·22	55·73	12·7%

INTERMEDIATE FRAMES.—American and Low Egyptian Cotton.

Speed of Spindles = 680 revs. per min.
Dia. of Full Bobbin = 4½ in.
Weight of Full Bobbin = 22 oz.
Dia. of Front Roller = 1¼ in.
Lift = 10 in.
Time lost in Doffing, etc. = 14 min. per set.

1·2	140	4·98	1·27	9·46	7·89	53·5	13·4%
1·4	130	5·38	1·376	9·01	6·44	50·84	10·9%
1·6	122	5·73	1·467	8·59	5·37	48·59	9·1%
1·8	115	6·08	1·554	8·22	4·57	46·47	7·7%
2·0	111	6·36	1·62	7·96	3·98	44·97	6·7%
2·2	105	6·75	1·72	7·59	3·45	42·88	5·8%
2·4	99	7·03	1·796	7·32	3·05	41·35	5·1%
2·5	97	7·18	1·832	7·17	2·87	40·53	4·8%

INTERMEDIATE FRAMES.—Good Egyptian and Sea Island Cotton.

Speed of Spindles = 650 revs. per min.
Dia. of Full Bobbin = 4½ in.
Weigbt of Full Bobbin = 20 oz.
Dia. of Front Roller = 1⅜ in.
Lift = 9 in.
Time lost in Doffing, etc. = 14 min. per set.

1·50	157	4·12	0·954	11·11	7·41	62·77	13·8%
1·75	146	4·45	1·03	11·04	6·31	61·37	11·7%
2·00	136	4·75	1·1	10·4	5·2	58·76	9·8%
2·25	129	5·04	1·17	10·08	4·48	56·95	8·3%
2·50	122	5·31	1·232	9·67	3·87	54·66	7·2%
2·75	116	5·58	1·293	9·29	3·38	52·48	6·3%
3·00	111	5·83	1·35	9·0	3·0	50·85	5·6%
3·25	107	6·04	1·4	8·8	2·71	49·77	5·0%
3·50	103	6·26	1·45	8·47	2·42	47·85	4·5%

ROVING FRAMES.—Indian and Low American Cotton.

Speed of Spindles = 1100 revs. per min.
Dia. of Full Bobbin = 3½ in.
Weight of Full Bobbin = 11 oz.
Dia. of Front Roller = 1⅛ in.
Lift = 7 in.
Time lost in Doffing, etc. = 13 min. per set.

Hank Roving.	Revs. of Front Roller.	Turns of Spindle to one of Front Roller.	Twist per inch.	Hanks per Spindle per day of 10 hours.	Lbs. per Spindle per day of 10 hours.	Hanks per week of 56½ hours.	Percentage of Time lost in Doffing, etc.
1·75	155	7·06	2·0	9·29	5·31	52·5	16·0%
2·00	146	7·5	2·122	8·84	4·42	49·94	13·9%
2·25	138	7·95	2·25	8·55	3·8	48·3	11·9%
2·50	131	8·3	2·37	8·25	3·3	46·61	10·4%
2·75	125	8·79	2·487	7·947	2·89	44·9	9·1%
3·00	119	9·18	2·6	7·71	2·57	43·56	8·1%
3·25	115	9·54	2·7	7·47	2·3	42·23	7·2%
3·50	111	9·9	2·8	7·24	2·07	40·93	6·5%
3·75	107	10·24	2·9	7·05	1·88	39·83	5·9%
4·00	103	10·6	3·0	6·8	1·7	38·42	5·4%

ROVING FRAMES.—American and Low Egyptian Cotton.

Speed of Spindles = 1050 revs. per min.
Dia. of Full Bobbin = 3½ in.
Weight of Full Bobbin = 10½ oz.
Dia. of Front Roller = 1¼ in.
Lift = 7 in.
Time lost in Doffing, etc. = 13 min. per set.

2·0	151	6·94	1·767	9·84	4·92	55·59	16·2%
2·5	135	7·76	1·976	9·25	3·7	52·26	12·2%
3·0	123	8·5	2·165	8·67	2·89	48·98	9·5%
3·5	114	9·15	2·33	8·246	2·356	46·59	7·7%
4·0	107	9·8	2·5	7·76	1·94	43·84	6·4%
4·5	101	10·4	2·65	7·38	1·64	41·69	5·4%
5·0	95	10·97	2·795	7·05	1·41	39·83	4·6%

ROVING FRAMES.—Good Egyptian and Sea Island Cotton.

Speed of Spindles = 900 revs. per min.
Dia. of Full Bobbin = 3½ in.
Weight of Full Bobbin = 10½ oz.
Dia. of Front Roller = 1¼ in.
Lift = 8 in.
Time lost in Doffing, etc. = 13 min. per set.

4·0	104	8·64	2·2	7·6	1·9	42·94	6·2%
4·5	98	9·15	2·33	7·2	1·62	40·68	5·3%
5·0	93	9·66	2·46	6·9	1·38	38·98	4·5%
5·5	88	10·13	2·58	6·65	1·21	37·6	4·0%
6·0	85	10·58	2·694	6·36	1·06	35·93	3·5%
6·5	82	11·0	2·804	6·11	0·94	34·52	3·1%
7·0	79	11·42	2·91	5·88	0·84	33·22	2·8%

JACK FRAMES —American Cotton.

Speed of Spindles = 1150 revs. per min. | Dia. of Front Roller = 1¼ in.
Dia. of Full Bobbin = 2¾ in. | Lift = 7 in.
Weight of Full Bobbin = 9 oz. | Time lost in Doffing, etc. = 13 min. per set.

Hank Roving.	Revs. of Front Roller.	Turns of Spindle to one of Front Roller.	Twist per inch.	Hanks per Spindle per day of 10 hours.	Lbs. per Spindle per day of 10 hours.	Hanks per week of 56½ hours.	Percentage of Time lost in Doffing, etc.
4·0	133	8·63	2·2	9·4	2·35	53·1	9·0%
4·5	125	9·13	2·33	9·0	2·0	50·85	7·7%
5·0	119	9·66	2·46	8·65	1·73	48·87	6·6%
5·5	113	10·13	2·58	8·3	1·51	46·89	5·8%
6·0	108	10·6	2·7	7·98	1·33	45·0	5·1%
6·5	104	11·0	2·8	7·73	1·19	43·67	4·6%
7·0	100	11·42	2·91	7·42	1·06	41·9	4·1%
7·5	97	11·82	3·01	7·27	0·97	41·0	3·7%
8·0	94	12·2	3·11	7·04	0·88	39·77	3·4%

JACK FRAMES.—Egyptian Cotton.

Speed of Spindles = 1120 revs. per min. | Dia. of Front Roller = 1¼ in.
Dia. of Full Bobbin = 2¾ in. | Lift = 7 in.
Weight of Full Bobbin = 8 oz. | Time lost in Doffing, etc. = 13 min. per set.

9·0	105	10·6	2·7	7·915	0·879	44·7	3·8%
9·5	103	10·87	2·77	7·737	0·814	43·71	3·5%
10·0	100	11·17	2·845	7·54	0·754	42·6	3·2%
10·5	98	11·38	2·913	7·41	0·704	41·87	3·0%
11·0	95	11·7	2·98	7·238	0·658	40·89	2·8%
11·5	93	11·97	3·05	7·089	0·616	40·05	2·7%
12·0	91	12·21	3·117	6·948	0·579	39·21	2·5%
12·5	89	12·48	3·18	6·818	0·545	38·47	2·3%
13·0	88	12·72	3·24	6·7	0·515	37·86	2·2%
13·5	86	12·96	3·305	6·58	0·487	37·17	2·1%
14·0	84	13·2	3·366	6·468	0·462	36·5	2·0%

JACK FRAMES.—Sea Island Cotton.

Speed of Spindles = 1050 revs. per min. | Dia. of Front Roller = 1¼ in.
Dia. of Full Bobbin = 2¾ in. | Lift = 6 in.
Weight of Full Bobbin = 6 oz. | Time lost in Doffing, etc. = 13 min. per set.

15·0	72	14·4	3·677	5·535	0·369	31·27	2·2%
15·5	71	14·68	3·739	5·457	0·352	30·79	2·0%
16·0	70	14·92	3·8	5·364	0·335	30·28	1·9%
16·5	69	15·14	3·857	5·296	0·32	29·88	1·8%
17·0	68	15·37	3·916	5·22	0·307	29·49	1·7%
17·5	67	15·63	3·98	5·145	0·294	29·07	1·7%
18·0	66	15·82	4·03	5·082	0·282	28·7	1·6%
18·5	65	16·04	4·085	5·011	0·271	28·33	1·5%
19·0	64	16·25	4·14	4·96	0·261	28·0	1·5%
19·5	63	16·49	4·2	4·88	0·25	27·57	1·4%
20·0	62	16·68	4·248	4·83	0·24	27·29	1·3%

CHAPTER IV

SUPPLEMENTARY NOTES

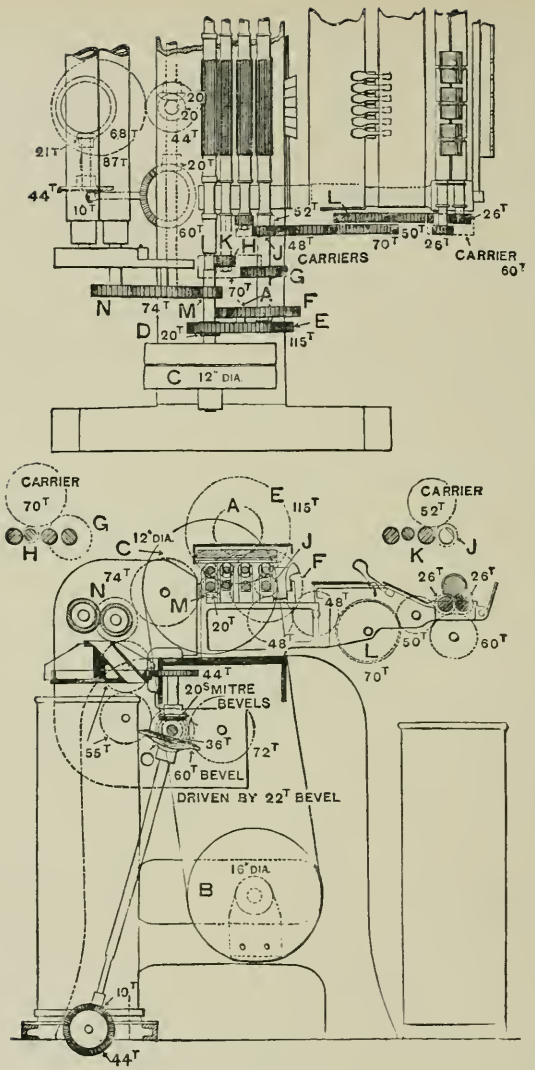
A GENERAL view of Dobson and Barlow's draw-frame is given in Fig. 113, which supplements those already given. An enlarged view of the upper part of the machine such as the rollers, stop motions, etc., will be found on p. 37, Fig. 22.

The upper view of Platt's draw-frame is sketched in Fig. 114, from which the stop motions can be readily understood. The arm O which operates the front stop motion is carried in slides. The strap-fork is coupled to S. Full can stop motion for K consists of a plate in the space M whose upward movement puts a pin in the path of the arm O and thus stops the machine.

A more complete view of Ermen's Clearer is given in Fig. 115 as fitted to Dobson and Barlow's draw-frame.

Drawing and Drafting of Cotton Fibres.—The drawing or drafting of the cotton fibres occupies an unusually important position in the preparing and spinning processes. There are two distinct phases of this attenuation of the fibres. In the first place, a short, bulky length of fibres is divided up, and the fibres distributed so as to form a longer and thinner or less bulky mass. This kind of attenuation or draft is to be found in bale-breakers, hoppers, openers, scutchers, card, drawing rollers in pre-

NOTE.—A very complete set of practical notes on these details will be found in the author's book, *Cotton Mill Management*.


20
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48T
20T
48T
50T
60T
L
70T
44T
20S MITRE
BEVELS
55T
36T
72T
60T BEVEL
DRIVEN BY 22T BEVEL
16" DIA
B
10T
44T

Fig. 113.

paring and spinning machines, and in the excess movement of the carriage of the mule. All these examples are definite drawing methods, and are spoken of as draft; the amount of this draft can be readily calculated. The dimensions of a bale of cotton compared with the dimensions of the laps of the opener produced from it, will give a ratio that represents the draft, just as the resulting sliver in the draw-frame compared with the number of ends put up will give us the draft.

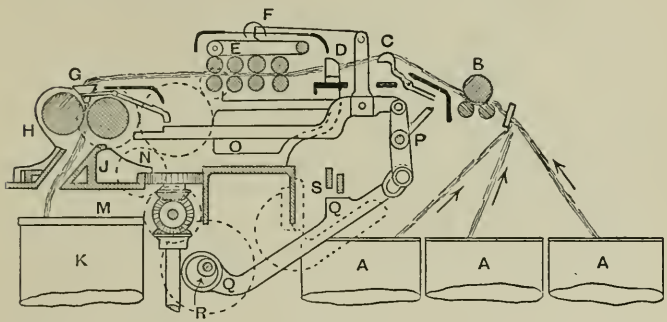

FIG. 114.

It is as well to note that the drawing action in most of the examples above is quite independent of what are called drawing rollers, and, therefore, the particular length of the cotton fibre, so far as the draft is concerned, is not a factor of much importance. For instance, the 3000 to 4000 of a draft between a bale and the lap (produced from it at the opener) has not necessitated any consideration being given to the length of the fibre so far as the draft itself is concerned. The same may almost be said of the draft of the card. When the length of the fibre is taken into account in either opening or carding, it is done for other purposes than drafting. Draft therefore in opening,

cleaning, and carding is purely and essentially a lengthening and a thinning process.

When the fibres have been reduced to a somewhat small

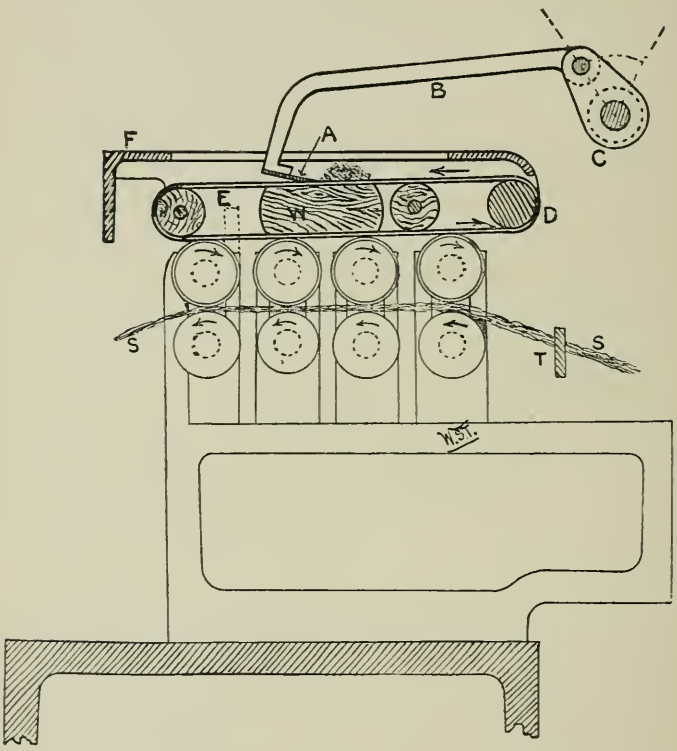

Fig. 115.

and fairly well-ordered condition, as in a sliver and a roving, another method must be adopted to attenuate the fibres, and this brings us to the use of drawing rollers. These consist of pairs of rollers adjacent to each other, one pair of which runs at a higher surface speed than the pre-

ceding pair. The cotton is passed forward by one pair of rollers, and the next pair gripping it carries it forward at a faster rate, and consequently draws the fibres apart longitudinally, and so lengthens the sliver or roving at the same time that it thins it or reduces its bulk.

Confining our attention to the purely attenuating process, it will be seen that a new set of conditions arises, for now the fibres are not carried along by air currents, needle points, or by rollers set wide apart, and between which there is the smallest travelling or carrying draft to keep the cotton slightly in tension. Presumably, we must have the various pairs of rollers carefully adjusted in their distance apart if we are to obtain a large draft between any given pair of rollers. This may be considered a fundamental practice in cotton spinning, and the setting of rollers to suit the average length of the fibres of the cotton is a basis throughout our spinning mills. Now, this universal practice and the tolerably fair results, in the majority of cases, that are attained with drawing rollers, as at present arranged, has led to the conclusion that the adjustment or setting of the rollers and their weighting is the real basis of good drawing and its accompanying effect of parallelising the fibres.

In spite of this, no student of cotton spinning ought to accept it as an axiom; in fact, no process or action in cotton spinning can be considered as other than tentative steps in the making of yarns. "Cotton Spinning" is not merely accepting present-day facts of our cotton mills, and the results of their mechanical operations, nor does it lie in remedying mechanical defects or delicate adjustments of parts; good mechanics can do this, but it lies in the reasoning faculties that can accurately deduce causes of failure or the correct procedure to adopt under given conditions.

Before we can commence considering the drawing action of rollers, it is necessary to have a clear conception of the fibres that are to pass through them. Judgment of fibres is usually based on hand-pulling, which gives a nice set of fibres of fairly regular length and quite straight, as in Fig. 116. This suggests the length of the fibres, and also, incidentally, their strength, if one tries to break them. It is certain that no practical man ever uses this hand-pulling test as a real test of the average length, but it supplies a basis, and in the mill, adjustments are made that allow for a shorter length than hand-pulling would indicate.

FIG. 116.

If a small pinch of any cotton is taken and the fibres measured and arranged, the result would be somewhat as in Fig. 117, wherein all the fibres are shown and not simply all the long fibres as in the hand-pulling test.

Now, cotton spinning has to do with all the fibres in a bale of cotton, and not merely the long fibres or even the average length of fibres. Wastes and short fibres may be taken out, but they leave the bulk of the fibres very little better than before, and even the product of the comber has its wide range of lengths of fibres from the shortest to the longest. Going a step further, it must be remembered that the cotton, up to the time it is in the sliver form, has been practically in a free condition, and, as in the card web, the fibres take up a natural position and are twisted and bent in a variety of forms; straight fibres are unusual in good cotton. In the drawing process we have to deal with these indiscriminately varied forms. Fig. 118 represents a

few of the naturally-shaped fibres. All of them are of exactly the same length, but all of the fibres in cotton, both long and short fibres, are of these varied forms, and they exist in these forms in the card sliver throughout its length. It has already been pointed out how difficult it is to even approximate to an average length on the supposition that all fibres lie straight in the bulk, but when

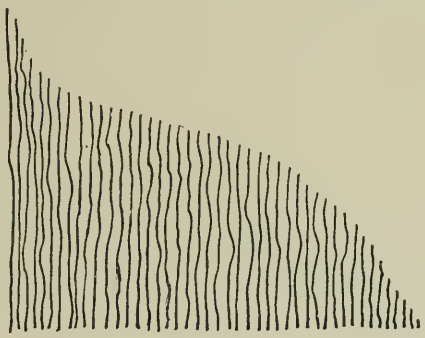

Fig. 117.

their actual disposition is realised, as depicted in Fig. 118, or even better when examined in the web of the card, the difficulty of estimating the average length is practically impossible. Suppose the six fibres in Fig. 118 were passed through two pairs of drawing rollers. We know definitely the length, and that all six are equal in length, a condition unusually favourable to ready decision in setting the rollers according to the prevailing practice. We know, of course, that the setting would be made so that the distance apart of the centres of the pairs of rollers would be slightly over the length of, say, No. 1 fibre. We also know that a marketable product would be the result of such a setting of the rollers. The facts in the case, however, are no reason

for not clearly understanding the process, and, as a preliminary, the student, as well as the practical man, must clearly realise the actual condition of the cotton that is submitted to the drawing action between rollers.

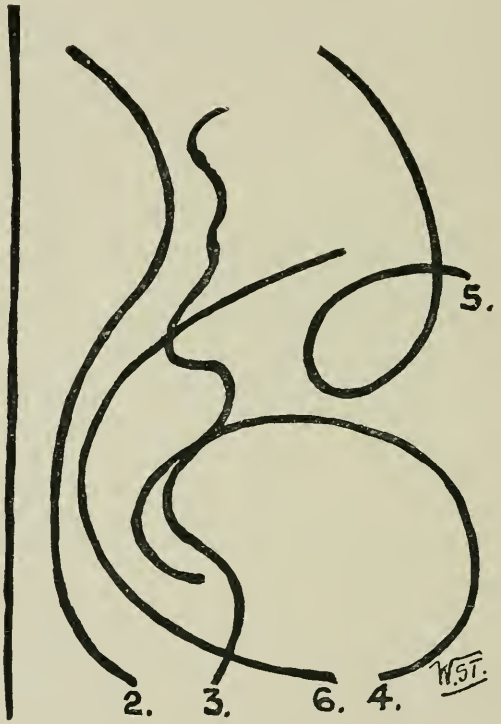

Fig. 118.

Present Arrangement of Drawing Rollers.—We will first consider the matter from the present-day arrangement of drawing rollers. These are of two kinds, viz. four pairs of rollers and three pairs of rollers, as shown in Figs.

119 and 120, the usual arrangement for average American cotton. Modifications, of course, are to be found, but they will not affect what follows :—

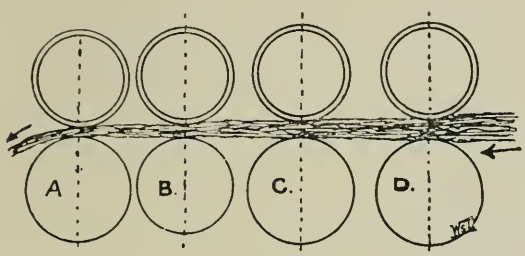

Fig. 119.

Fig. 119 arrangement is used for the drawing of cottons in the sliver form, whilst Fig. 120 represents the drawing rollers for rovings whether on the flyer frames or the

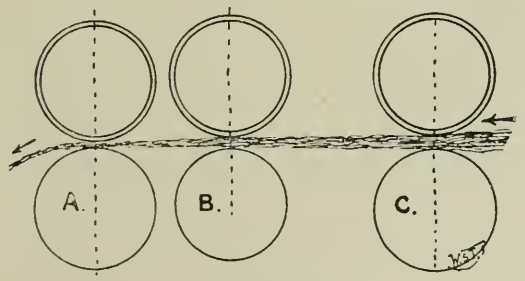

Fig. 120.

spinning machines. A draft or drawing action takes place between each pair of rollers so that the cotton emerges much finer than when it was introduced. This draft is not distributed equally between the pairs of rollers; for instance, in Fig. 119 the draft between C and D would be

about 1·4, between B and C and between A and B about 2·83, so that the total draft would be about 8. The same occurs in the three lines of rollers, for between B and C in Fig. 120 there would be a small draft, and the bulk of the draft put between A and B; in other words, the main part of the draft or drawing action occurs between the pairs of rollers that are nearest together, and whose centres apart differ very little from what is supposed to be the average length of the fibre. The rest of the drawing action occurs between pairs of rollers whose centres are set apart a greater distance than the length of the staple.

Drawing Short Staple.—The action that takes place between two rollers whose centres are wider apart than the staple of the fibre, is somewhat as follows:—

Let C and D in Fig. 121 represent the centre lines of two rollers; these will be spoken of as the gripping points (small circles separate so rapidly that the grip of two small circles may be considered to act only at the line joining their centres). Several full-length fibres are shown in dark lines, and these are surrounded by the usual mass of fibres of the sliver or roving. All the fibres between A and C will move forward at the speed of the rollers at C, and they will continue at this speed as individual fibres until they are free from the grip of the rollers at C. The mere fact of the rollers being able to draw the sliver forward from the cans indicates that the fibres are all entangled, and the accumulated pull of the fibres causes the sliver to move bodily forward without being pulled asunder or even drawn ever so slightly. (Interesting and very valuable tests may be made on the strength of slivers by allowing a sliver to hang vertically, and paying it out until breakage occurs; the weight of the broken-off piece of sliver represents the breaking weight. Their value would

lie in the direction of indicating variation in carding, mixing, and character of the cotton. In draw-frame and comber slivers much valuable information could be obtained as to the effectiveness of the operations and extraction of waste.)

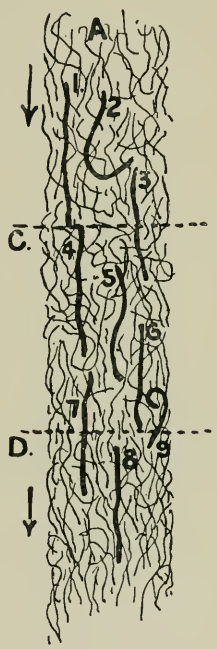

Fig. 121.

When the fibres emerge from the grip at C, and even while passing through the rollers, they come under the influence of the higher surface speed of the rollers at D, and those fibres already within the grip of D will be pulled forward and slide over those that are still under the influence of C. This sliding action will tend to straighten both fibres and so cause the fibres to become more parallel to each other. At the same time, a large number of the fibres that are free from the grip of both C and D are carried forward just as they are, and in many cases are not only not straightened out, but, on the contrary, are still further bent or distorted. According to the degree of entanglement, we find fibres that remain under the influence of the grip at C until they pass to the grip at D, and many others that come under the direct action of the grip at D immediately they leave the grip at C. These several states of varied movement of the fibres leads to irregularities in the reduced but longer sliver delivered by the rollers at D. These irregularities will not be too pronounced as long as the distance between C and D is not too much in

excess of the length of the fibres. The expression "too pronounced" is used advisedly, and applies only to the testing methods used in our mills to detect variations. A series of successive yards of sliver from a card or first head of drawing will always exhibit a fairly wide range of variation, but if each yard were cut up into inch lengths, the variations in weight of each inch would be surprisingly great.

Wide spaces between successive lines of rollers are responsible for the perpetuation and increase of these irregularities, and they are found in the draw-frame and the spinning machine rollers.

Spacing of Rollers.—In the openers and scutchers there is a long space between the cages or cage rollers and the calender rollers. A draft exists at this point, but it is merely "a carrying draft," yet even this small draft produces a tearing apart effect which is noticeable, if carefully observed, on some machines. In any two pairs of rollers set at a distance apart in excess of the length of staples, there will always be this tearing action as distinguished from a true drawing effect. In the very early stages of cotton spinning, it was recognised that the further apart rollers were spaced the less draft could be used, and we have to-day a kind of compromise, based on that experience, that fixes the space between the back and middle roller at such a distance in excess of the length of the staple that the draft between them has to be the lowest possible consistent with this setting. These two factors are of such a fixed nature that they have assumed the character of mere structural details outside the consideration of the spinner and concerning only the manufacturer of the machines. So much so is this the case that 90 per cent of spinners could not tell one what the draft is between the back and

middle rollers of his fly frames or spinning machines, nor the distance between the centres of these two sets of rollers. Something that is bred in the bone, that has almost become instinct, tells our spinners that if this spacing is exceeded, even with the low draft, or if the distance is kept and the draft increased, the result will be chaos.

Roller Settings.—The matter does not end here. The experience that gave us our back and middle roller settings also decided, in a way, the front and middle roller settings. These old spinners found that by reducing the space between the rollers one could increase the draft without the irregularities being too noticeable, so they closed up the front and second pairs until the distance of their centres apart was almost equal to the presumed length of the staple, and this has remained the practice until the present time in our card-room machinery. A limiting factor, however, entered into the question, for it was found that care had to be exercised as to the amount of draft between the two rollers, and as the draft between the back and middle rollers must of necessity be small, owing to the wide spacing between their centres, so the draft also must be limited between the front and middle rollers so long as their distance apart is in excess of the length of the staple.

This limitation of draft accounts for the small drafts used in the card-room, and the necessity that follows of repeating operations and multiplying machinery to attain some desired result. Immediately the rovings are passed on to the spinning-room, a new aspect of the drawing action opens out. We still note that the back and middle rollers are set far apart, but experience forbids, even here, anything more than a low draft between them. but between the front and middle rollers there is scarcely a limit to the

draft that is put in, and this becomes possible simply because the front and middle rollers are set within the length of the fibres, *i.e.* the distance between the centres of the front and middle rollers is a little less than the presumed length of the fibres composing the roving.

Before asking ourselves why this large increase is possible, we must recapitulate a little. In the first place, it must be noted that a judgment of the length of the fibres is based on the fibres drawn straight by the hand-pulling test, and on this test is based the settings of rollers. In experienced hands, this test for length allows for the shorter fibres, and so judges an average length, which is somewhat shorter. It has, however, been pointed out that there are comparatively few straight fibres in raw cotton, and that the great bulk of the fibres are bent and curved in all directions. Since this is the condition as they lie in the sliver, and to a less extent in a roving, it naturally follows that the average length of fibres is much shorter than is generally assumed as a basis for setting the rollers. After passing the first head of drawing, some of the fibres are a bit more straightened, and this effect is increased at each succeeding drafting process, but a proportion of these bent and curved fibres, of all lengths, remain in the roving and are spun into yarn. Excessive draft in the draw and fly frames would spew these fibres out in a very prominent manner from the front rollers, and any indication of this spewing is always a clear sign of too much draft in the rollers, or, what amounts to the same thing, that the rollers are set too far apart, and so allow too many of the bent and curved fibres to lie free between the grips of the rollers.

If the fibres of a comber lap are carefully measured and compared with the fibres of the finished comber sliver, the

difference between them is only comparatively small in spite of the enormous difference in appearance and feel. On measuring the waste that has been taken out, it will be found that this also presents no very great difference from the lap or sliver. What has really happened is that the comber has extracted a certain percentage of the curled, bent, and curved fibres which form the roughening element in the cotton, and consequently leaves the remaining fibres smooth and straight, hence the great change seen in the resulting sliver. Curved fibres still exist in the combed sliver, combed yarns will show any amount of them, short and long, and these, of course, are not straightened, rather the opposite, by the setting of the rollers in the comber draw-box, and in subsequent drafting processes, before reaching the mule.

A further point to note is the use of some form of weighting applied to the rollers to increase the grip. This weighting is so heavy, on account of the bulkiness of the material (slivers and rovings) in the card-room, that the draft and the parallelisation of the fibres must, of necessity, take place in the free space between the rollers. It is the sliding of the fibres over each other in the space between the grips that we rely upon for parallelisation or straightening out of the fibres. Practically, no fibres are drawn out from between the grip of the bottom and top rollers in card-room machinery, and whilst this is effectual to some extent, as already explained, an opposite effect is always associated with it which brings in its train considerable irregularities whether of carded or combed material.

It may be interesting to note now the action of the mule rollers. These are supposed to be set within the length of the fibres so that, presumably, the front and middle rollers both grip the same fibres. As a whole,

however, this cannot be the case if the rollers are only set a short distance within the length, say $\frac{1}{16}$ or $\frac{1}{8}$ of an inch. Owing to the great amount of drafting that has taken place in the card-room and multiplicity of machines the cotton has passed through, there are undoubtedly a certain proportion of fibres that have been straightened. As these are momentarily stretched between the two holding grips, any curved fibres in contact with them will be drawn somewhat straighter if they are in the grip of one of the rollers. This action, however, can only affect a comparatively few fibres, so that most of the curved fibres are still free between the closely-set rollers, and consequently are taken forward in their curved condition and incorporated in the yarn. If the rovings are of combed cotton, the fact that a proportion of the curved and irregularly shaped fibres have been removed reduces the possibility of this happening to the same extent, so that more regular yarn is made. Theoretically, there is no free space between the front and middle rollers of a mule, but, actually, the presence of unstraightened fibres always constitutes a free space. The more there are of these unstraightened fibres the less is the draft that can be put in any machine, and the less of curved fibres that exist in the cotton, so the draft can be correspondingly increased. The whole problem of drafting between rollers depends, therefore, on the degree of straightness that we can produce among the fibres from the earliest stage onwards.

Underlying this obvious statement is a mass of practical problems worthy of consideration and solution. At the moment, attention must be directed to the draft and setting of rollers, and accept the web of the card as it is given to us. Collect carefully a piece of this web and, realising that it will be passed through drawing rollers,

ask oneself what is the average length of the fibres. In Fig. 122 a small piece of such a web is given. A close examination will show that practically every fibre is equal in length, and this length is about equal to the distance between the lines A and B. A hand pull of this cotton would give us ideal conditions for judging length, but clearly this length cannot be used as a basis for setting our rollers. Take a fibre that lies parallel to A and B; it is straight, of full length, but evidently, for the purpose of setting rollers and drafting, it has no length at all, and in

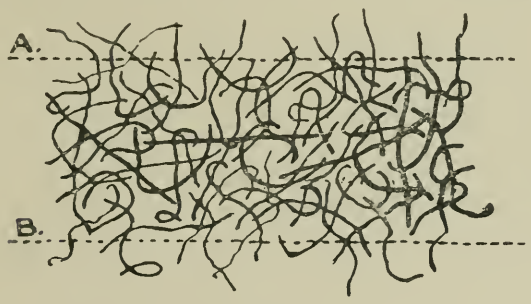

FIG. 122.

the same connection all the other fibres vary considerably in length according to their position in the web or sliver. With even the ideal conditions shown in Fig. 122, the length of the fibres for drafting purposes is something extremely difficult to estimate, but in any case such an estimate must, of necessity, be far shorter than the actual length of the fibres. If an actual case is taken, and we look at our web and see every gradation of length among the entangled fibres, a judgment of an average length for the purpose of drafting and straightening becomes a mathematical problem of some complexity. After some considerable amount of drafting, length becomes a more

tangible factor, especially after combing, but this is due chiefly to the fact that we have reduced the quantity of fibres and kept the draft low at each step of the reduction.

What has been said leads logically to the conclusion that the parallelisation or straightening of the fibres can be carried out more effectually by eliminating all possibility of any free space for any shape or length of fibre between the drafting rollers. This means, practically, that centres of rollers must be brought as close together as possible, so that one pair of rollers draws the fibres from between the nip or grip of the other pair of rollers, and straightens the fibres as they lie in the grip. The natural consequence of this condition implies that rollers must be small in diameter to enable them to be closed up, and also that little or no weight must be put on those rollers through which the cotton is drawn. Length of fibre becomes of small consequence under these conditions; draft can be increased considerably, and greatly improved straightening of the fibres effected. In the case especially of mule rollers, the middle and back top rollers must be as light and small as possible.

It will be an easy matter to deduce from what has been described in regard to present methods of drafting and setting of rollers, that they are not conducive to regularity of slivers or rovings. Granted that a perfect card sliver could be produced, *i.e.* every inch of it uniform in weight, if this sliver were put singly through the drawing frame, flyer frame, and spinning machine rollers it would emerge from each set of drawing rollers in a very irregular condition. The irregularity thus caused by the drawing rollers would not of necessity be cumulative, as some irregularities would be neutralised in passing through several drafting

operations. The great factor which neutralises some of the irregularities, however, is the doubling process that occurs in all or most of the machines mentioned, and so produces a much less irregular roving from the front roller of the spinning machine than would be the case if a single sliver only were subject to the drafting in all the machines. Drawing rollers, under present conditions, are invariably a cause of great irregularities in every machine on which they are used.

Draft in the Rollers of Draw- and Fly-Frames.—As a rule the drafts between the four pairs of rollers on a draw-frame are not based on any definite system. The total draft is known, and this usually takes the form of a whole number such as six or eight. This number is then divided up into a small draft between the 3rd and 2nd lines, and a much larger draft between the 2nd and front rollers. It is not often that the draft is altered between the back and 3rd or 3rd and 2nd line of rollers, they remain as set by the machine maker, and as small wheels are used on these lines of rollers, a change of a tooth would make a big change in the draft. Added to this, it happens that nothing can be seen as to what is occurring between these lines of rollers, so beyond calculating the total draft, and making any change by altering the speed of the back roller, very few people trouble themselves about the distribution of the drafts. The amount of draft, of course, ought to depend on the setting, and the setting naturally, in an orthodox mill, depends on the length of staple, so that it scarcely seems advisable to have a fixed rule for the drafts that is applicable to any cotton and to any head of drawing. This fact, however, does not prevent the following rule being followed in a number of well-managed mills :—

Draft between the 1st and 2nd rollers = square root of total draft.
,, ,, 2nd ,, 3rd ,, = cube root of total draft.
,, ,, 3rd ,, 4th ,, = the rest or remainder.

(1) Example—

Total draft to be 6.

Draft between the 1st and 2nd rollers	$= \sqrt{6} = 2{\cdot}449$	increase 36 %
,, ,, 2nd ,, 3rd ,,	$= \sqrt[3]{\ } = 1{\cdot}817$	,, 35 %
,, ,, 3rd ,, 4th ,,	$= \frac{6}{2{\cdot}45 \times 1{\cdot}8} = 1{\cdot}36$	,, 36 % over sliver.

$2{\cdot}449 \times 1{\cdot}817 \times 1{\cdot}36 = 6$, total draft.

(2) Example—

Total draft to be 8.

Draft between 1st and 2nd rollers	$= \sqrt{8} = 2{\cdot}828$	increase 41 %
,, ,, 2nd ,, 3rd ,,	$= \sqrt[3]{8} = 2$	,, 43 %
,, ,, 3rd ,, 4th ,,	$= \frac{8}{2{\cdot}828 \times 2} = 1{\cdot}412$	,, 40 % over sliver.

$2{\cdot}828 \times 2 \times 1{\cdot}412 = 8$, total draft.

It will be noted in the first example that the draft between the 1st and 2nd rollers is 1·388 times more than between 2nd and 3rd. The draft between 2nd and 3rd is 1·331 times more than between 3rd and 4th. In other words, the drafts are almost equally proportioned between the rollers. The case is even more clearly seen in the second example, for although there is a slightly larger percentage increase of draft between the 2nd and 3rd over that between 3rd and 4th, than exists between the 1st and 2nd over the 2nd and 3rd rollers, the proportion is fairly equal.

The meaning of this will be seen at once if the drafts are plotted on squared paper as in Figs. 123 and 124. Commencing with one of a draft (which of course is no draft, but represents the condition of the cotton between the can and the back roller), the drafts are marked out on the 1st, 2nd, and 3rd vertical lines in each diagram, and the curve joining them is almost a straight line. In using

numbers to express draft we obtain a fairly clear idea of what has happened to the cotton in its totality, but neither the figures nor the diagrams in Figs. 123 and 124 give us as clear an idea as is requisite, especially in the intermediate drafts; we get a bulk idea instead of a detailed view of the drafting. Now drafting is simply the sliding of fibres over

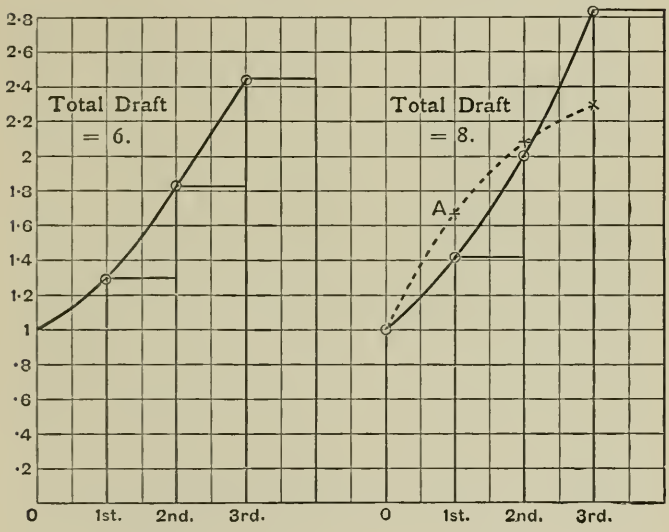

FIG. 123. FIG. 124.

and among each other and their rearrangement in a longer and thinner condition. If we have "two" of a draft this means that, say, one foot of sliver has been lengthened out to two feet, and in this drafting some fibres have not moved whilst others have moved one foot from their original position. In moving this distance there has been a sliding effect among the fibres. It is this effect of drafting that must be clearly grasped, and perhaps one way of enabling

this to be done is to plot the attenuation of the fibres resulting from a series of drafts. Let us first calculate the attenuation from the drafts obtained by rule in Examples 1 and 2. For this purpose we will assume one inch fed into the back roller.

(3) Total draft = 8.

Length fed to back roller		= 1	inch.
,, delivered by 3rd roller	= 1 × 1·4 . . .	= 1·4	inches.
,, ,, 2nd ,,	= 1·4 × 2 . . .	= 2·8	,,
,, ,, 1st ,,	= 2·8 × 2·82 . .	= 8	,,

(4) Total draft = 6.

Length fed to back roller		= 1	inch.
,, delivered by 3rd roller	= 1 × 1·36 . . .	= 1·36	inches.
,, ,, 2nd ,,	= 1·36 × 1·817 . .	= 2·47	,,
,, ,, 1st ,,	= 2·47 × 2·45 . .	= 6	,,

By plotting the lengths obtained in (3) and (4), which is done in Figs. 125 and 126, we obtain a very distinct impression of how the cotton has been drawn out by the drafting based on the rule given in (1) and (2). The original inch shown at O in a thick line has been lengthened out by an amount A in the first draft, by a length B over the length of the 1st draft, and by a length C over the length of the 2nd draft.

It scarcely needs to be pointed out that the lengths A, B, and C are the real factors to be decided upon in all drafting problems between successive lines of drafting rollers, and that these lengths ought to be decided upon before fixing the drafts. They will naturally vary according to the condition of the fibres in the sliver or roving; on the staple, and the setting of the rollers. It scarcely seems reasonable to suppose that there ought to be the same attenuation of the fibres in the intermediate stages at the last head of drawing as at the first head, and a mere glance at the diagrams in Figs. 125 and 126 will suggest that the first draft between the back and 3rd roller is

too small, and the draft between the 2nd and front is too large.

The rule of "square root, cube root, and the remainder" would appear to be one of those haphazard rules formed for the convenience of memory and to relieve the judgment;

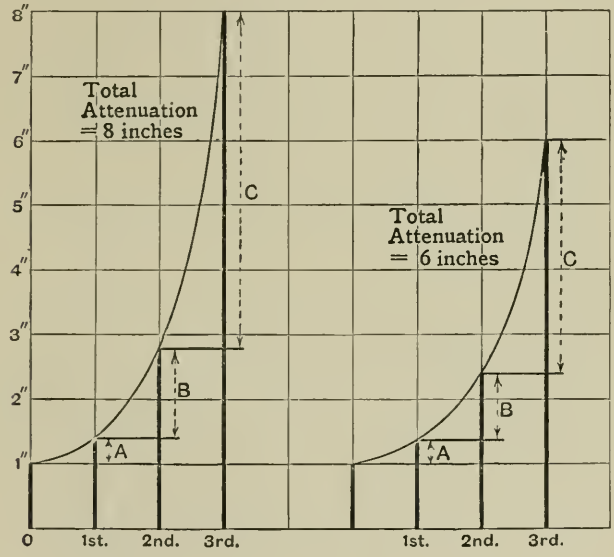

Fig. 125. Fig. 126.

it has no practical basis, and is certainly not scientific in spite of square root and cube root being incorporated in it.

A practical method of fixing the drafts would be to decide how much you will attenuate the fibres in each stage of the drawing rollers, and this must be a question of judgments based on experience and knowledge of the condition of the cotton and rollers. An example is given to illustrate this.

Assume one inch of sliver from the can. We ask ourselves how much can this be drawn out, and decide that the fibres can slide over each other to the extent of a maximum of $\frac{5}{8}$ of an inch. This will give us $1\frac{5}{8}$ to be drawn out at the next pair of rollers, the 3rd and 2nd pairs. Again use our judgment as to how much we can lengthen this $1\frac{5}{8}$ inches. As it has been somewhat straightened, we may reasonably lengthen it to $3\frac{1}{2}$ inches. This $3\frac{1}{2}$ inches must now be lengthened finally, between the 2nd and front roller, to 8 inches, thus increasing its length by $4\frac{1}{2}$ inches. The above can be stated thus—

(5) 1 inch in the first draft has been drawn out to $1\frac{5}{8}$ inches.
$1\frac{5}{8}$ inches ,, second ,, ,, ,, $3\frac{1}{2}$,,
$3\frac{1}{2}$,, ,, third ,, ,, ,, 8 ,,

or—

In the first draft the fibres slide over each other $\frac{5}{8}$ inch.
,, second ,, ,, ,, ,, $1\frac{7}{8}$ inches.
,, third ,, ,, ,, ,, $3\frac{1}{2}$,,

With these lengths decided upon by judgment, it is an easy matter to calculate the drafts to obtain them. These drafts will be as follows—

(6) Draft between back and 3rd roller $= 1\frac{5}{8} = 1{\cdot}625$.
,, ,, 3rd ,, 2nd ,, $= 2{\cdot}153$.
,, ,, 2nd ,, front ,, $= 2{\cdot}285$.

It must be acknowledged that these drafts do not appear satisfactory, but this is simply because our ideas of drafts are so hazy. If the figures in (5) are plotted on squared paper we obtain a picture of the lengthening process between the rollers, and in Fig. 127 we note that a quite reasonable amount of drafting is indicated. Further, if the lengthenings at A, B, and C are represented as "drafts" as in (6), and these are plotted, we get the diagram as in Fig. 128, which is quite different from the curve in Fig. 124 which is based

on the rule. To show this difference the curve in Fig. 127 has been drawn on Fig. 124 in a dotted line at A.

Almost all drafting between drawing rollers results in the production of irregularities. This is due to the setting, weighting, and drafts. A perfect card sliver, if such a thing

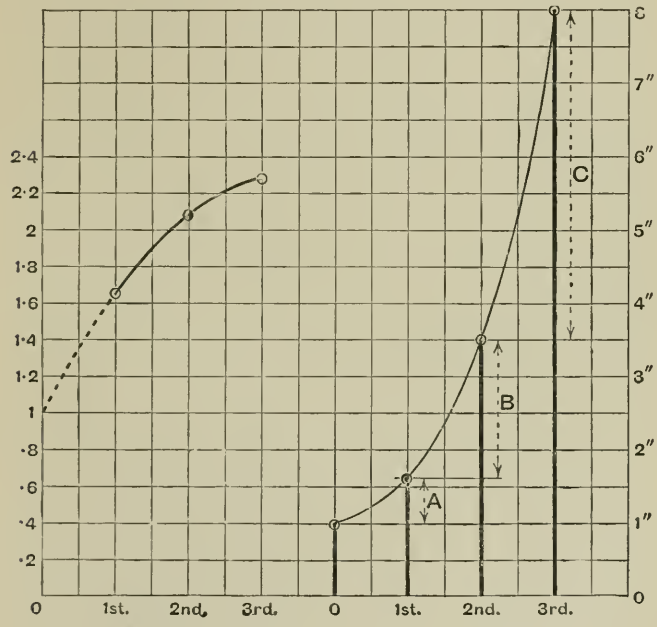

Fig. 128. Fig. 127.

could be produced, would become imperfect in passing through a series of drawing rollers. This can readily be tested by passing a single card sliver through a head of drawing or successive heads. Doubling is the factor that disguises somewhat this action of the rollers, but even doubling fails to eliminate the irregularities that are being

constantly added as the cotton passes from one machine to another.

A further factor that makes for irregularities is the driving of the top roller by frictional contact with the cotton passing between the pair of rollers. This has a disturbing effect on the fibres, and on some machines makes quite a difference to the draft, but even when this is not influenced, the disturbance and rearrangement of fibres passing under a weighted roller, and through which this weighted roller is driven, must be a serious cause of irregularities. Our methods of testing results by long lengths have lowered the standard to which we ought to attain. So long as this lower standard exists most work done on cotton machines may be thought fairly good, but the student is asked to study carefully the inner actions of the machines, and to realise that much remains to be done and new ideas must be formulated that will inspire the responsible man to set up a high standard and adopt newer methods to attain it.

Long Fibres in Comber Waste.—The presence of crossed and also curled fibres of good length in the comber lap almost of necessity leads to their elimination in combing, and they go into the waste. Good straight fibres are by no means uncommon in the comber waste, and these are caused by faulty settings and timings of the various organs. Every action of the comber requires exactness in its mechanism, and the moment when the action begins and ends must be definitely timed. The student of the comber scarcely needs to be told that late nipping, opening nippers too soon, too early action of top comb, too premature or late detaching, etc., will result in long fibres being mixed up with the waste. The adjustments of rollers and nippers in regard to being parallel to each other, to the uniformity

of the pressure of weights and springs, to the sufficiency of the pressure to ensure the right grip, are all necessary to prevent waste of long fibres. Faulty laps, as already explained, will be a serious source of good fibres being carried away, and if the grip of the nippers is not uniform, or the holding surface or line of the nippers is irregular through wear or damage, it will be impossible to prevent long fibres getting into the waste.

Combing Action and Number of Fibres in a Comber Lap.—If No. 60's is being spun from sakel cotton, there will be an average of sixty-five fibres in the cross-section of this yarn. Suppose a 410 grain per yard lap is used on the comber, the cross-section of this lap will contain about 192,000 fibres. The seventeen rows of needles on the cylinder of the comber will contain about 11,000 needles, and these needles will pass through the cotton, say, four times, so that 44,000 needles will be used to comb 192,000 fibres. This gives, on an average, one needle to every $\left(\frac{192,000}{44,000}\right)$ four fibres. From this we deduce that the comber does not comb every individual fibre but only small groups of fibres. There may be a number of fibres individually combed, but if so there will be so many more in groups that are not combed. It is suggested to the advanced student, and to those occupying responsible positions in the mill, that it may prove beneficial to realise the number of fibres in slivers, rovings, and yarns, and to make it a kind of basis on which to reason out some of the problems that confront the practical man in his daily work.

Comber Waste Collector.—A brief mention is made on p. 90 of a comber waste collector termed an *aspirator*. This system is coming into more general use, so that a drawing is now given showing its general features. Two

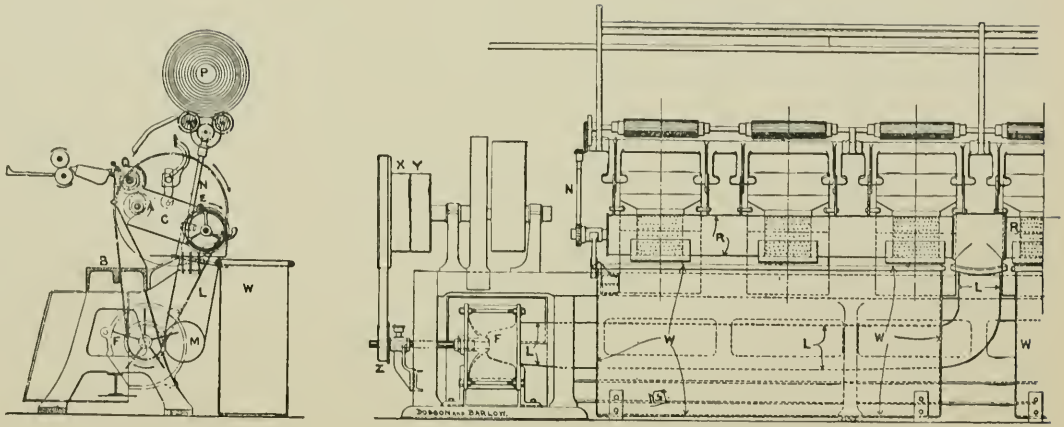

FIG. 129.

factors are responsible for the use of the aspirator, viz. the large amount of dust resulting from the brush, and also the neppy character of the waste when a doffer comb is used, this neppy waste resulting in a reduced value when the waste is sold. In Fig. 129 a back view of the comber is shown with the apparatus in position, and a section of the machine giving an end view. A slowly revolving drum R, driven from the lap rollers at N, runs along the back of the comber. The drum is in communication with a pipe L at its middle point, and this pipe L is coupled to a fan F which exhausts the air from the revolving drum R. The drum is fitted with perforated sections at each head, and these sections are cased in by sheet metal at the front, the casing extending so as to include the brush and back of the cylinder. Dampers are fitted within the drum or cage, so that as the waste is brushed from the cylinder it is drawn at once on to the uncovered part of the perforated section. All dust and minute fibres are thus sucked through the cages and on to the fan; the longer fibres adhere to the drum and are carried round, being slightly consolidated by a roller E resting on the drum. The waste thus takes on the form of a sheet, and as it passes over the back of the drum and being free from air pressure, it falls naturally into the receptacle W.

A more detailed view of the section of the apparatus is given in Fig. 130, the reference letters being the same in each drawing.

Preparation of Cotton for the Comber.—In considering the question of preparing cotton for the combing process, our starting-point must be the card sliver. The condition of the card sliver is more or less an open book to us, for the card web presents a clear picture of the whole of its structure, and every individual feature of which this

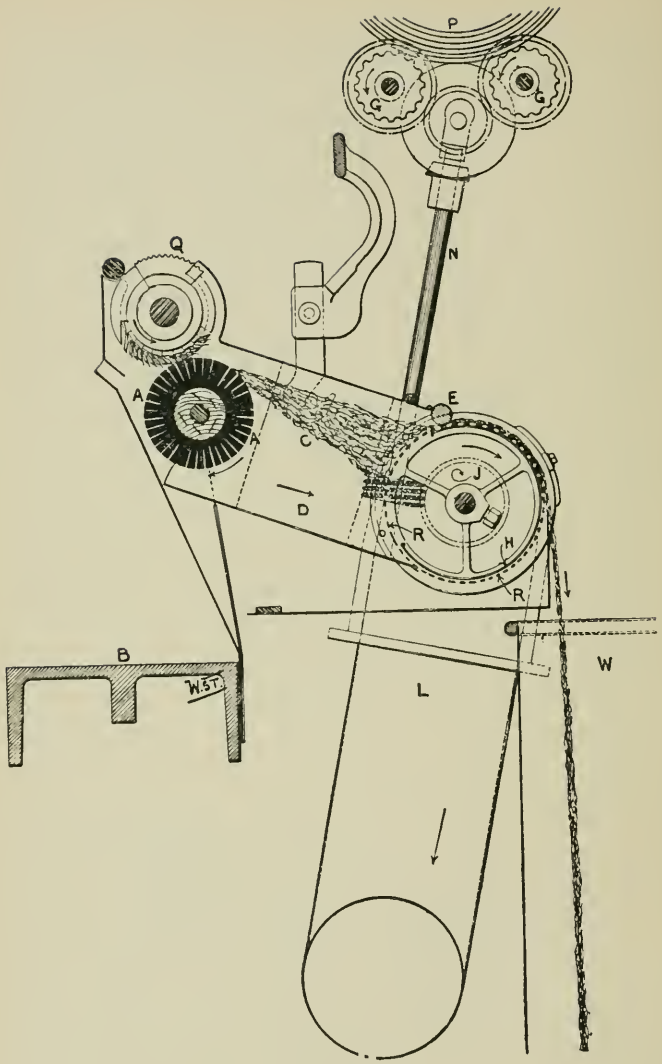

FIG. 130.

whole is composed is, or ought to be, well known. Much of this knowledge is, of course, easily obtained by the unaided eye; some require the aid of optical methods, and a not unimportant part is only definitely ascertained by a careful testing of weight for length. This latter test for irregularities is seldom carried out, except in a crude form, for the simple reason that general experience indicates the probability that all card slivers may be expected to show a considerable range of irregularity, and consequently that doubling is an absolute necessity in order to reduce the irregularities to a minimum. An important question now arises as to where this doubling process should take place. Before this can be answered, a further feature must be considered.

The needles of the comber pass through the sheet of cotton presented to them. These needles will straighten those fibres that are held by the nippers, and comb out or extract all the fibres that are not so held. These extracted fibres will naturally consist of short fibres, together with the longer fibres that happen to lie in the cotton in a bent or curved condition. Any needle coming into contact with small entangled groups of fibres, such as neps, will also carry them away. Irregularly disposed fibres therefore form a fair proportion of the waste taken out by a comber. From this it may be concluded that an important feature in the efficient working of a comber depends on the sheet of cotton being composed of a continuous series of parallel fibres. A second question now arises as to where these fibres can be made parallel.

Irregularity of the thickness of the lap, or sheet of cotton across its width, is a further factor of importance. If the nippers press upon an irregular thickness of cotton, this pressure will be of a varying character, and the presence

of thick and thin places across the lap will result in the cotton not being held at all in some parts of the nipper, or only feebly held. This condition will naturally result in not only excessive waste containing good long fibres, but also in the production of irregularities in the resulting comber sliver. A third question arises, therefore, as to how can the lap be made uniform in thickness across the width?

The accompanying sketches (Fig. 131) will show in a somewhat emphasised form the varying character of comber laps.

No. 1 represents a uniform thickness of cotton lying between the nippers, and this may be assumed to be normal. If the lap is irregular lengthwise of the lap, but uniform across its width, the normal thickness will only occur occasionally, for the thickness between the nippers will vary, say, between the two extremes, as in Nos. 2 and 3.

Any one acquainted with the working of the comber will recognise what this constantly varying thickness of the feed must mean in lowering the efficiency of the machine and the value of its products.

The varying irregularity of the disposition of the fibres projecting from the nippers may be roughly illustrated as in No. 4.

All the loose fibres in the projecting sheet A are in a position to be taken out as the needles pass through. Many of these free fibres are taken out, but since there is an excess of fibres over the number of needles, there must, of necessity, be many free fibres that are untouched by the comber needles.

It must be recognised that the projected sheet of fibres, held by the nippers and presented to the action of the cylinder needles, is in a very entangled and disordered

condition, and that looped fibres, both ends of which are held by the nippers, are not uncommon. Observation shows this to be the case, and it is confirmed by the broken and distorted needles which indicate that some unusual

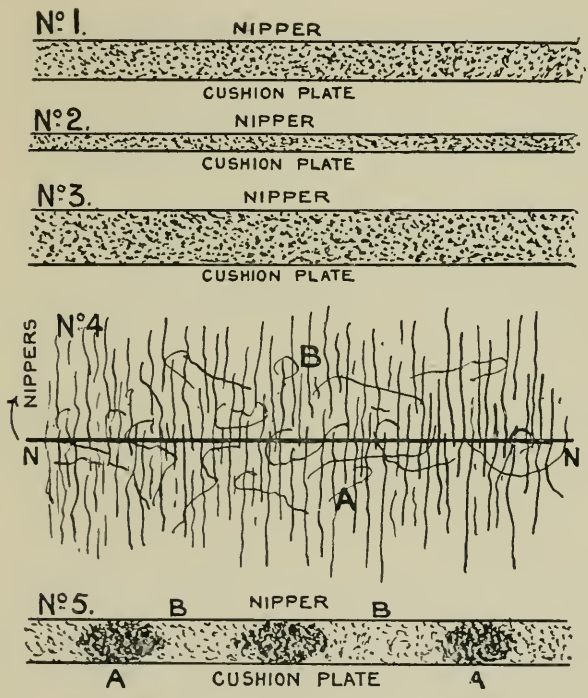

FIG. 131.

effort has been necessary in passing through entangled fibres. Broken and bent needles are a sure indication of an inferior preparatory process, and it may be taken for granted that, where broken or bent needles are found, some needles have escaped damage by simply breaking the fibres.

One very important effect has been produced by the passage of the needles, viz. the fibres have been straightened and laid in some kind of parallel order, thus giving a uniform lustre and a smooth silky feel to the cotton.

At the same time it must be emphasised that it is highly desirous the fibres should be presented to the comber in as parallel a condition as our present system is capable of producing.

Our next point to notice is the irregularity that may exist along the width of the lap.

In No. 5 a rough sketch is given to illustrate an irregular thickness of lap between the nippers.

Thick and thin places are shown at A and B respectively. The pressure between the nippers cannot be uniform along their full width if irregularities of this kind exist in the lap. The natural consequences would be the plucking out of fibres and groups of fibres from the parts B, a high probability of considerable broken fibres at the points A; also bent and broken needles may be anticipated.

Three important characteristics that should be possessed by the lap put up at the combers must be regularity in the length; regularity in the width; the fibres composing the lap to be in parallel order. At this point the reader may well ask—Why comb the cotton when it has attained the conditions just mentioned? The query may be dismissed by casually observing that a comber lap never possesses the characteristics enumerated; they are purely ideal. In practice, however, the ideal ought to be kept in view, and the cotton from the card prepared in such a way as to approach the ideal as near as our present methods and machinery will permit.

The machinery at our disposal in preparing comber

laps consists of drawing frames, sliver lap machine (Derby doubler), and ribbon lap machines.

The methods might be stated as follows :—

(1) Card sliver to sliver lap machine and direct to comber.

(2) Card sliver to lap machine, then to ribbon lap machine, and on to comber.

(3) Card sliver to draw-frame, then to sliver lap machine, then to ribbon lap machine, and on to comber.

(4) Card sliver through two heads of draw-frames, then to sliver lap machine, then to ribbon lap machine, and on to comber.

or put into a concise form :—

1.	2.	3.	4.
Card	Card	Card	Card
Sliver lap	Sliver lap	Draw-frame	2 heads Draw-frame
Comber	Ribbon lap	Sliver lap	Sliver lap
	Comber	Ribbon lap	Ribbon lap
		Comber	Comber

This list is sufficient for the mill man to recognise the amount of doubling and drawing a comber lap has undergone, and his reason alone will enable him to work out the relative efficiencies of each of the four methods. Normal conditions, within a reasonable range of counts and a due sense of economy of production, are important factors in deciding the system, but the making of the best yarn out of a given cotton enters largely into the question, and is sometimes the most important factor of all.

It is not difficult, and possibly it has often been done, to test the merits of the four methods, but there is such a

lack of definite information that one is led to give the figures of some tests that have been made. The cotton used was the same in all the tests, the same card sliver and the comber settings remained the same throughout.

(1) Card Sliver lap machine Comber	18 per cent of waste at comber.
(2) Card Sliver lap machine Ribbon lap machine Comber	12 per cent of waste at comber.
(3) Card Draw-frame Sliver lap machine Ribbon lap machine Comber	10 per cent of waste at comber.
(4) Card 2 heads of Draw-frame Sliver lap machine Ribbon lap machine Comber	9 per cent of waste at comber.

The mere fact of taking out a certain percentage of waste is not a sufficient indication of good combing unless one has a clear knowledge of how the comber lap has been prepared. It would certainly be of interest to the practical man and the student to seriously reason out the problems that arise as to what has actually taken place among the fibres of cotton in the four experiments, and not dismiss the matter by merely suggesting or asserting that extra doubling and drawing has caused the difference between the four different methods.

THE WEIGHTING OF ROLLERS

Factors governing Weighting.—The weighting of rollers is extensively practised in textile machinery, and for various purposes. From this fact alone it might be considered obvious that the pressure put upon rollers would be of unusual importance in effecting some given purpose The measure of the efficiency of the weighting would be indicated by the care exercised in adjusting the pressure to suit particular conditions of length of staple, drafting, spacing, thickness of cotton, hanks, speeds, etc., and even extends into the relative value of springs, dead weights, and lever weighting. All these factors are parts of the problems involved in a rational system of weighting rollers, and their importance is fully recognised by the men in authority in our mills.

No Standard.—Paradoxical as it may appear, efforts at utilising weights at their best advantage do not prove successful in the direction anticipated, with the consequence that for apparently identical purposes authorities will have heavy weights, others light weights, and others again anything between extremes, and the peculiar fact remains that each authority that has settled on these weights considers them the correct weights for his purpose. On the other hand, so many have experimented with the weighting and found such varying results, that they have simply left the matter in the hands of the machine-maker. It may almost be said that in the bulk of cases a mill accepts the machine-maker's decision as to weighting. If fairly normal results are obtained by this weighting, then the mill authority will go through life under the impression that those particular weights are the best, and they become a kind of standard for all future work.

A Varying Factor.—Interesting as the subject is, it is not our purpose here to work out the weighting of rollers for any particular set of conditions. Our object is rather to show how weighting is practically a constantly varying factor on any given roller, and that when we are

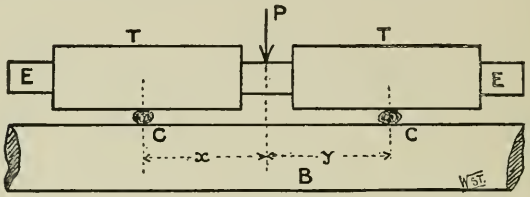

Fig. 132.

under the impression that, say, a 10-lb. pressure is on a roller, it is not 10 lbs., but a pressure that goes through a cycle of variations in pressure. These variations, it may be added, are responsible for a considerable amount of the irregularities in the products turned out by the machines.

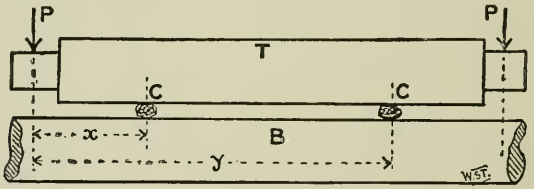

Fig. 133.

Two Ways to exert Pressure.—There are two ways in which pressure may be applied to a roller, viz. by pressure being exercised on the centre of a roller, and by the pressure being applied at each end of the roller.

Fig. 132 represents a diagram of pressure being applied to the centre of a roller, the top roller T being free in

its end bearings E, and capable of rising and falling vertically to accommodate the thickness of the cotton C that may be going through. B is the bottom roller.

In Fig. 133 the weighting is applied at the ends of the roller. The top roller T is free, as in Fig. 132.

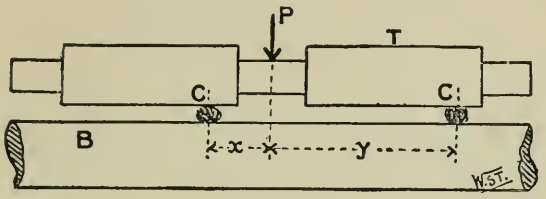

FIG. 134.

The pressure in each of these two cases may be applied by springs, by lever weighting, by dead weights, *i.e.* hanging weights at the points P, or by self-weighting, *i.e.* with no additional weight beyond the weight of the roller itself, in which case the weight or pressure will act at the middle point in the roller.

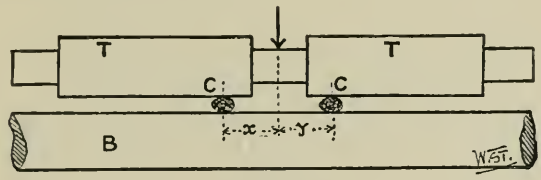

FIG. 135.

Now suppose a pressure of, say, 20 lbs. is acting at P in Fig. 132, and the two strands of cotton C C are at equal distances on either side of the direction of the pressure P, then the pressure on each of the strands will be 10 lbs., and this will be the pressure whether the strands are as in Figs. 132, 135, or 136.

If a traverse motion is used which does not maintain

the strands at equal distances in respect to the direction of pressure, this equality of pressure vanishes. In Fig. 134 the strands of cotton are shown at unequal distances from the line of pressure. The total pressure on the two strands C and D will, of course, be 20 lbs., but each strand will

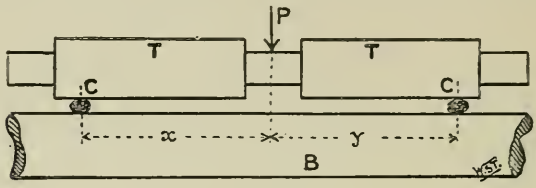

Fig. 136.

be subject to a different pressure. The pressure on C will be $13\frac{1}{3}$ lbs. and that on D will be $6\frac{2}{3}$ lbs. = 20 lbs. This, of course, is a wide difference in pressure, and it is naturally varying from moment to moment as the traverse guide moves the cotton to and fro. This variation of pressure is taking place on two strands of cotton that are presumably

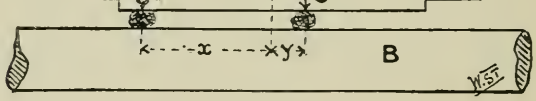

Fig. 137.

alike, and working under exactly the same conditions of draft and speed. In face of this it is surprising that such dogmatism still persists in cotton mill circles as to the efficiency of the certain weights or pressure to be applied to rollers. Here we have (and it is common throughout our mills) two rovings, one weighted twice that of the next roving, and yet no one would examine this particular

feature in looking for a course of irregularity or other peculiarity of the resulting roving or yarn.

A self-weighted roller, as in Fig. 137, works under the same varying conditions of varying pressures for the two

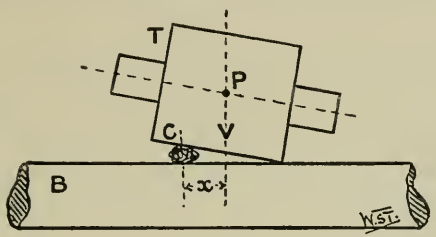

FIG. 138.

strands of cotton, save that the weight is very small, and being small it can scarcely be considered a weight but merely a holder and guider, so that the pressure does not act or function in the same way as in rollers that are deliberately weighted. There are cases where the self-

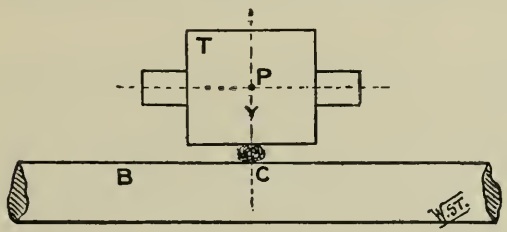

FIG. 139.

weighted roller only has one end going through, as in Fig. 138.

It will be seen that the only spot for the cotton to receive the full weight of the roller is when it passes directly under the middle. If the cotton passes to one side of the middle line, the top roller looses its balance and tips,

so that the pressure is lessened the farther away the cotton moves from the centre. This can be seen in reference to Fig. 139.

Referring to Fig. 136, a condition may arise similar to

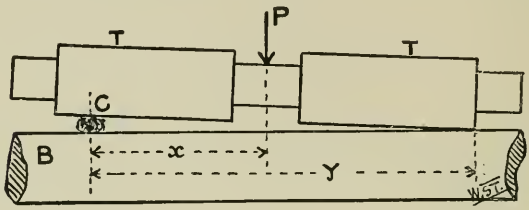

Fig. 140.

that shown in Fig. 140. Here we have one end down and the other going through. This causes one end of the roller to rest on the bottom roller at M, whilst the other end rests on the cotton at N. It will readily be seen that the cotton will be subjected to a varying pressure as it traverses its length of the roller.

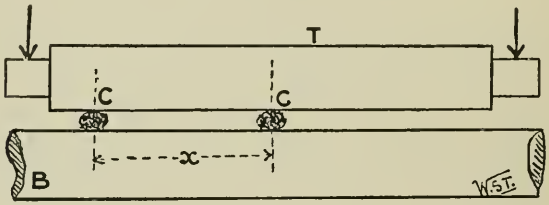

Fig. 141.

So far, the thickness of the cotton is of little consequence on the pressure effect, but in rollers weighted at their ends the thickness becomes important. In Fig. 133 it will be seen that so long as the two strands of cotton are each at equal distances from the ends or from the middle, they will be subject to equal pressures, but if from any cause they

are at unequal distances there may be a wide variation in pressure. Fig. 141 will illustrate this.

Now if, instead of taking two strands of cotton, we use a lap or a series of strands, we obtain a uniform pressure throughout the length if the cotton is uniform in thickness, but if the cotton is irregular in thickness, then the pressure will vary and very frequently there may be no pressure at all. This, of course, is easily seen, and the consequences in the production of irregularities are only too apparent in scutchers, cards, draw-frames, etc. Fig. 142 will indicate the condition.

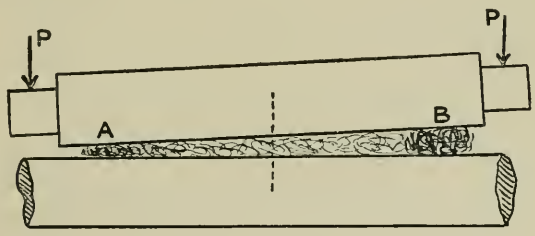

Fig. 142.

If the normal thickness were going through at A, and a thicker portion at B, the pressure would act at A and B, and leave the intervening space between A and B free from pressure, so that there would be no holding or gripping effect either to bring the cotton forward in the correct form, or to prevent the cotton already between the rollers from being drawn or plucked out bodily by such organs as beaters, takers-in, or other rollers. On the supposition that the two ends were weighted equally, a thick portion of cotton passing through the middle of the roller would balance the roller and act as a fulcrum to it, with the consequence that there would be no pressure on the cotton going through on either side of the centre line. This will

be quite clear from Fig. 143, where an equal pressure is applied at P and P, and a thick piece of cotton or a thick portion of sliver is passing through at C, which is the centre of pressure resultant of the two pressures of P and P. The cotton at C will naturally be subject to the full pressure or total pressure of the two levers or dead weights acting at P and P, and thus leave the cotton on either side of C practically free from pressure.

The examples already given are based on the supposition that the axes of the top and bottom rollers are parallel to

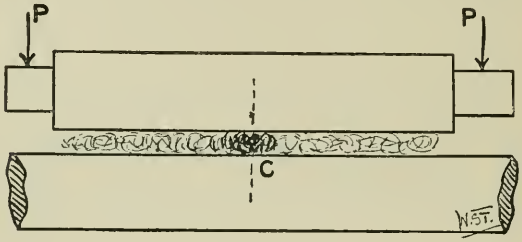

Fig. 143.

each other. It is possible that there are cases where the pivots or bearing of the top roller have become worn; when this has occurred so that both ends have worn equally, the top roller will occupy a position forward of its correct position, but its axis will still be parallel to that of the bottom roller. This altered position will naturally result in the lengthening of the distance between the grip of two pairs of successive rollers. This can easily be allowed for in the setting, and is scarcely a matter of importance unless in any given machine the two roller ends of one roller have worn more or less than the two roller ends of another roller. This would, of course, cause a difference of setting between the two rollers. Adjustable

cap bars would enable even a case of this kind to be readily set correctly. If, however, the two ends of a top roller are worn unevenly, or the axis of the top roller is not set parallel to the bottom roller, the top roller will not bed evenly on the bottom roller. In such a case the grip of the top roller, whether self-weighted or weighted, will be of a very varying character and unreliable as a drafting organ.

A Neglected Subject.—All the diagrams used are purposely somewhat exaggerated, but they point out clearly a phase of cotton spinning that is too often neglected. The principles involved belong to a very elementary phase of mechanics, so that it has not been considered necessary to work out numerically the varying pressures. If our technical schools would fit up a few models of rollers, and by means of spring balances actually test the pressures on rovings and yarns at different positions along the rollers, it would be a matter of intense interest to students, and probably of considerable value in suggesting solutions to some problems associated with irregularities that are constantly cropping up in the mill.

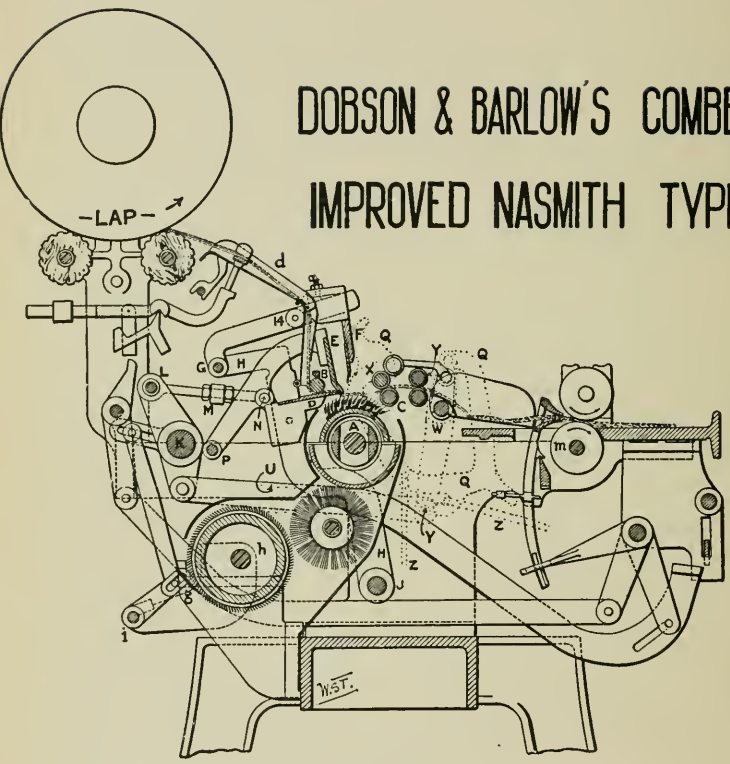

Fig. 144.

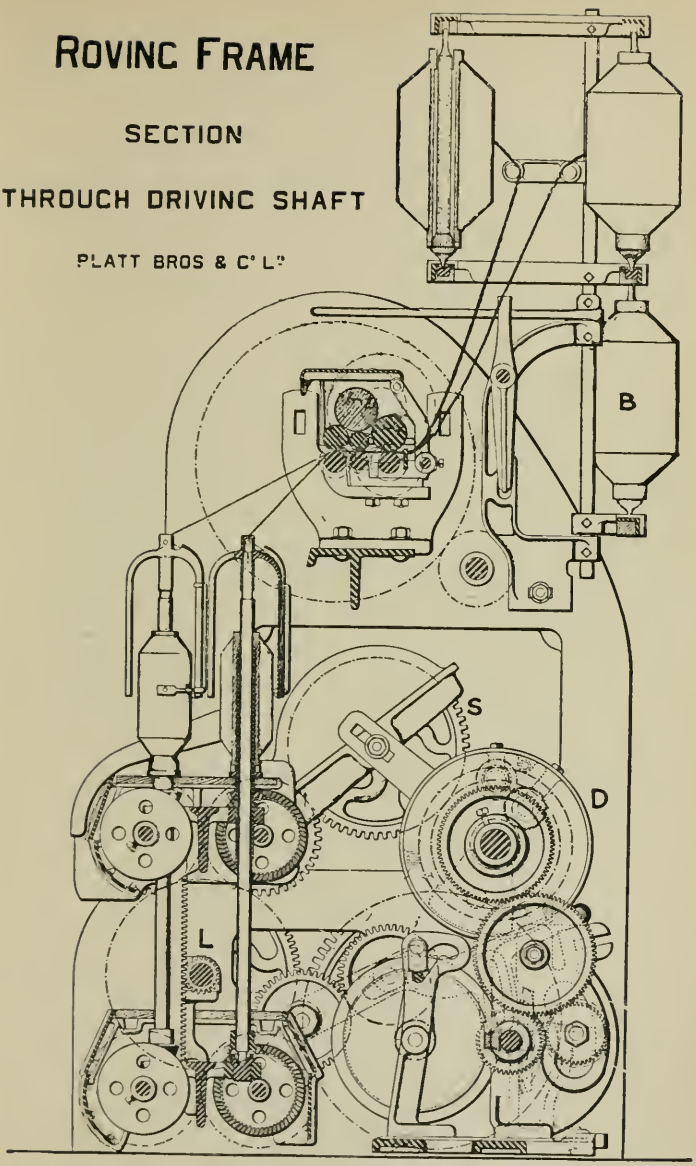
ROVINC FRAME
SECTION
THROUCH DRIVINC SHAFT
PLATT BROS & C° L°
B
S
D
L

FIG. 145.

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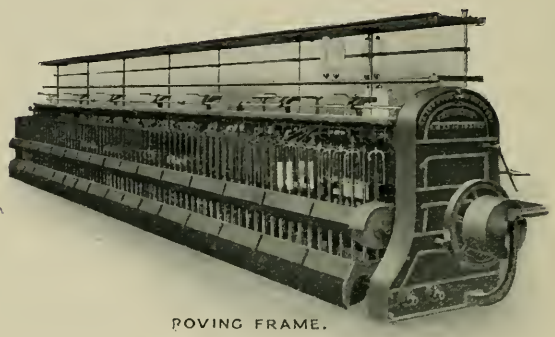

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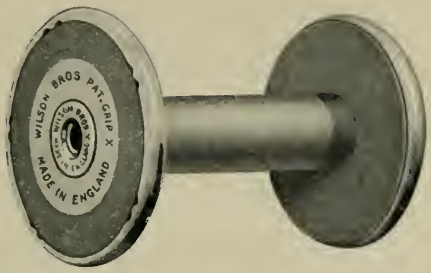

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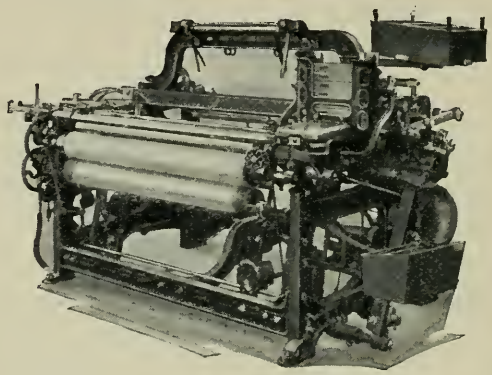

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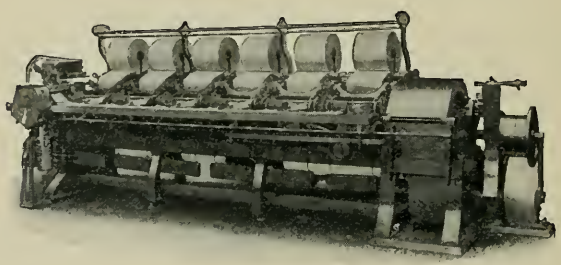

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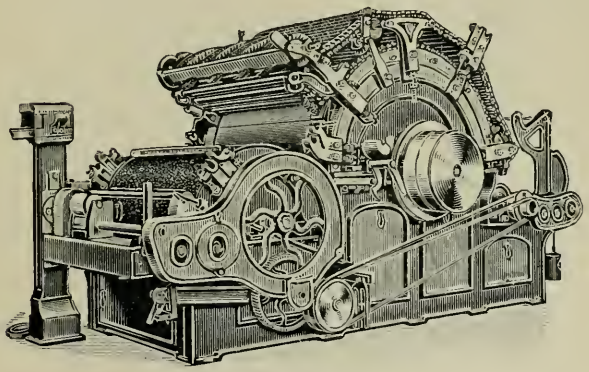

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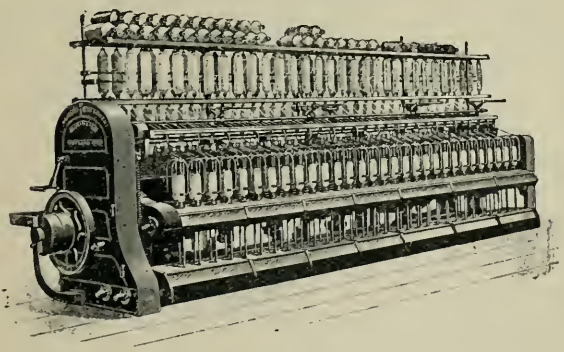

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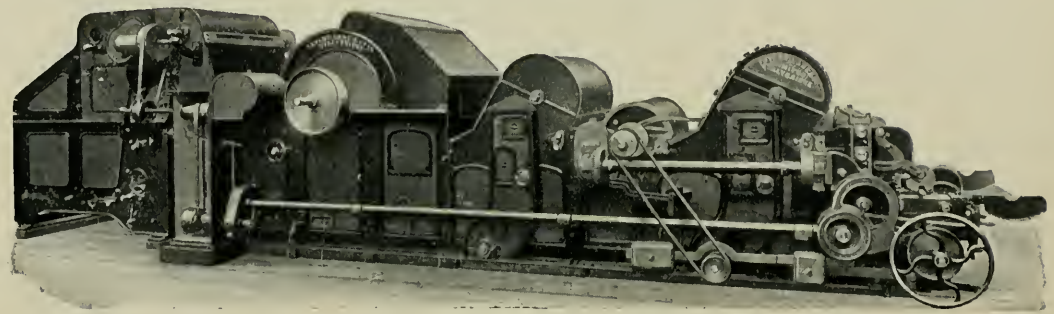

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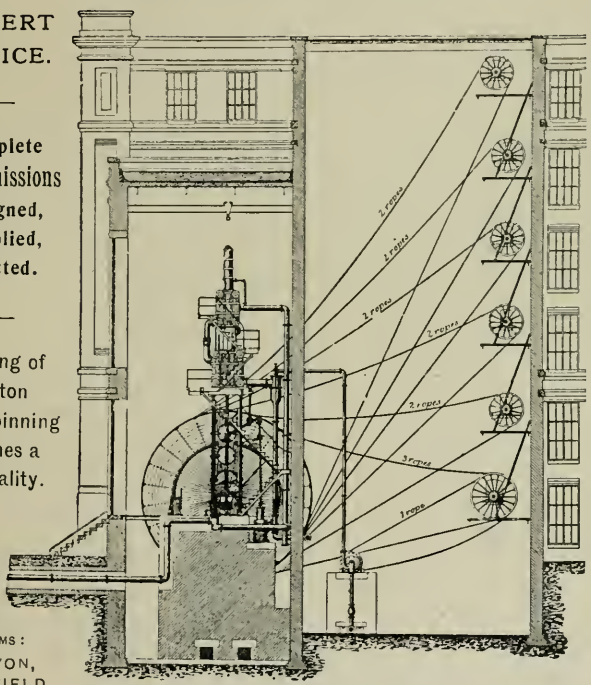

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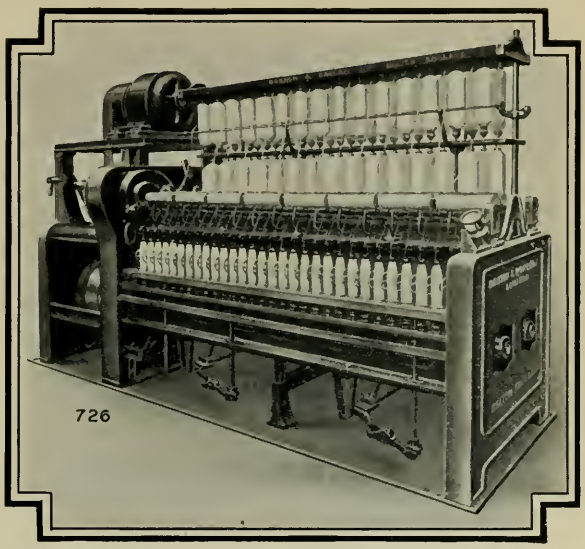

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